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TOPICAL REVIEW

Blockchain Technology Applications in Healthcare Supply Chains–A Review

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ABSTRACT Understanding the prospective of blockchain technology and its uses in the healthcare sector is essential so that its considerable implementation can support the industry's much-needed digitization. Furthermore, blockchain can provide answers to the issues in the healthcare industry today. Blockchain's features like security, traceability, transparency, cost efficiency etc. can help bring supply chain transparency, health record management and prevent drug counterfeiting. Blockchain has emerged as a promising technology with great ability to bring changes to the healthcare sector. Therefore, this study aims to comprehend the current state of blockchain technology research in the healthcare supply chains. Further, it presents potential repercussions and the potential routes it may open for future research initiatives in this area. A systematic literature (SLR) process has been used and conducted in two stages. In the first stage, articles were identified through literature search and were subjected to keyword selection, database search and screening process. Finally, 124 papers were categorized through bibliographic coupling. A detailed investigation of these included papers was performed in the second stage with descriptive and content analysis. The results reveal that research related to blockchain applications or implementation is at a nascent stage. The publications in this area have been rising steadily over the past few years. When it comes to publishing in this field, India is the most productive nation while IEEE Access is the most productive journal. Applications for blockchain technology in healthcare include medical insurance, remote patient monitoring, medication supply chain management, electronic health records (EHRs), and more. The most popular use case is EHR management. The analysis further conveys that findings are less generalizable due to more theoretical or less empirically designed studies published in this domain. This study will help stakeholders, policymakers, researchers, and managers in taking strategic decisions regarding the adoption of the technology in the healthcare industry. This study is done concerning the blockchain's use in the healthcare sector context, so other emerging technologies and sectors not taken must be considered while generalizing the results. This study is among the few up-to-date consolidated attempts to present a systematic literature review and bibliometric analysis for assessing blockchain technology's potential in the healthcare sector. It provides an overview of the published work with implications and proposed cluster-wise future research directions.

INDEX TERMS Bibliographic coupling, blockchain, healthcare, supply chain, systemic literature review.

I. INTRODUCTION

The healthcare supply chain is a complex network involving various parties. Different stakeholders are involved in the value chain, with varying interests, like suppliers are interested in maximizing their profits, whereas healthcare workers are concerned about patient healthcare and safety [55]. These conflicting goals reduce the coordination among the stakeholders and make the work challenging. Further, healthcare sector has been facing challenges of rising healthcare services costs, fragmented patient records which are not interoperable, medical data security, control of medical data, counterfeit

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drugs, frauds related to insurance claims and prescription management, and complexity and expensiveness of healthcare supply chains [26], [112], [128].

The healthcare sector has still not seen digital transformation and has not transformed in the same way as other sectors. To provide patients with better treatment, the healthcare sector must adapt technologically. Incorporating technologies like blockchain can prove its significance in the healthcare industry [59]. By tackling the present issues in healthcare, blockchain can completely transform the industry. It stores and shares sensitive healthcare data in a secure, private, and trustworthy way using decentralized consensus mechanisms and cryptographic algorithms. In addition to seamless data exchange, it can help connect different healthcare systems and provide real time access to patient's past data, reducing the tendency of redundant tests [12]. Patients can securely control their healthcare data through blockchain while maintaining consent and privacy. Thanks to blockchain-enabled rights and permissions, patients can exchange their data with authorized parties. The technology can help improve the traceability and transparency of drug supply chains, reducing the risk of counterfeit drugs [1]. Technology's security and transparency can reduce fraud by enhancing the validity of medical insurance claims and enhancing the trustworthiness of clinical trial results.

Previously, different studies tried to explore blockchain research in healthcare. Attaran [12] summarize health-related blockchain products and major players providing solutions across various applications, as well as identifying potential and difficulties for integrating blockchain technology in healthcare. Ali et al. [7] classify the blockchain related articles into challenges, benefits and functionalities in healthcare, manufacturing, financial and government sectors. Balasubramanian et al. [13] suggest a paradigm for assessing preparedness that considers the intricate interactions between various underlying causes, institutional mechanisms, and social structures, as well as all significant stakeholders. The framework's relevance and utility are established by applying it to the healthcare industry in the United Arab Emirates, based on a comprehensive literature review. Kraus et al. [68] conduct a SLR regarding the state-of-the-art in healthcare digital transformation. The authors divide the previous research into five clusters: workforce practices, organizational elements and management consequences, patient-centered approaches, workforce efficiency by healthcare providers, and socioeconomic issues. These clusters are connected to create a model that illustrates how different technology implementation strategies improve service providers' operational efficiency. Clauson et al. [158] presented a review of opportunities and challenges associated with blockchain's use in healthcare supply chains. The study focuses on pharmaceutical supply, medical devices and public healthcare sectors.

Rejeb et al. [101] conduct a bibliometric review to understand blockchain trends in healthcare. The authors conduct co-occurrence analysis and identify productive academic institutions, countries, and well-known writers in addition to the scholarly output and the annual total number of authors' developmental trend. Sookhak et al. [113] outline a framework for classifying both current and upcoming advancements in the access control field. A taxonomy based on themes for blockchain-based access control techniques is also provided to identify the security flaws in the current approaches and emphasize the essential security needs for creating a way of granular access control.

Ramzan et al. [147] discuss the potential of blockchain technology and present the limitations, open research issues and future research directions. Fiore et al. [157] provide an overview, through SLR, of the ways in which blockchain technology has been applied to address supply chain (SC) difficulties in the pharmaceutical, medical device, blood, organ, and tissue industries. These discussed studies are presented in detail in table A1 of the annexure.

From the established literature, it is evident that there is a need to understand the potential of blockchain technology, its applications in the healthcare sector so that its significant implementation can contribute towards the much-required digitization of the healthcare sector [144]. Moreover, blockchain has the potential to become an answer to the existing healthcare challenges. Therefore, it becomes crucial to comprehend the state of blockchain technology research in the healthcare supply chains, what implications it can have and what pathways it can make way for research activities for possible future developments in this field. So, this led us to take up the following research questions for this study-

Q- What is the development status and dynamics of blockchain technology research in the healthcare supply chains?

Q- What are the implications and future research directions regarding blockchain technology's use in Indian healthcare supply chains?

This article focuses on the literature divided into five different clusters communicating blockchain's evolution, its advantages, adoption status as well as challenges, healthcare issues, emerging areas and blockchain's applications in the healthcare supply chains. Our study adds to and expands upon prior blockchain research in the field of healthcare through descriptive and content analysis. To address the research objectives, explain the current state of blockchain technology in healthcare supply chains, and identify potential future applications, this study carried out a thorough analysis of the literature. Firstly, articles of blockchain technology, healthcare, and supply chain-related, focusing on blockchain work in healthcare applications were identified through a thorough literature search. Then, these articles were divided into clusters through bibliographic coupling. Secondly, an exhaustive investigation of these studies was performed with descriptive and content analysis. The study's findings will be pertinent and insightful for healthcare professionals and research

scholars working in this field, adding to the body of knowledge. It will provide a better understanding of both the state of the research now and trends in its advancement. The aim of this study is to enhance blockchain related research, encourage new applications and provide fresh avenues for blockchain knowledge propagation in the healthcare sector. It provides valuable information on this topic in ideas, conclusions, research gaps, and cluster wise directions for future work. This work is a beneficial contribution to the researchers and the healthcare sector as the overview of the technology's impact on this complex and promising field is sincerely presented.

The rest of the study has been arranged as follows: Section II describes the background of blockchain technology and section III explains the research methodology adopted for the study. Section IV justifies the findings of the study in terms of descriptive and content analysis. Section V presents the discussion part in detail and section VI outlines the implications, limitations, and future research directions. The conclusion is finally presented in section VII.

II. LITERATURE

This section sheds light on knowledge regarding blockchain technology's background and a comparison among the recent literature review studies with the present study is presented.

A. BACKGROUND ON BLOCKCHAIN TECHNOLOGY

Blockchain technology is a distributed ledger technology that combines two characteristics, i.e., peer-to-peer communication and cryptography [120]. It first came into the picture through Satoshi Nakamoto due to the growing popularity of the bitcoin white paper [30], [34]. It is a continuous chain of blocks that gets stored in an extensive computer database, which is formed with the help of various interconnected devices like computers, phones, or other systems, connected virtually or manually [32], [40], [103]. Each block contains transaction or communication data whose security and privacy are maintained through cryptography. Its validation is being made through a consensus mechanism by the network peers eliminating the third party [17], [75], [114]. Blockchain technology is mainly applied in cryptocurrency and financial transactions, but more industries like healthcare and manufacturing are exploring its applications [20], [76], [77]. The driving factors for the technology's implementation include less dependency on massive servers, reduced requirement for trusted parties, redundant work reduction, cost-effective and maintaining data integrity, privacy, and security [48]. Blockchain has various uses like storing medical records, tracking goods, recording, verifying transactional details, concluding binding agreements, etc. It strengthens security and provides privacy protection to the associated system. It is of a distributed nature and allows records to be stored on many connected systems that keep the same information. Hackers need to breach more than 50% of the challenging systems to hack the whole network [58].

There are four types of blockchains – private, public, consortium and hybrid. A private blockchain or permissioned blockchain, has a single operator who controls who can access and add data to the blockchain network. Public blockchains or permissionless blockchains are of decentralized nature with no individual or organization controlling them. The network is open to everyone, and anyone can join in on its main activities and at the same time users remain anonymous. The advantages of public blockchains include immutability, easy accessibility, and high security whereas disadvantages include high energy consumption and low throughput. Public blockchains examples include Ethereum, bitcoin, Litecoin etc. [139]. A private blockchain, on the other hand, requires users on the system to be verified which is not in public blockchains. They are centralized or partially decentralized, and their users can be identified. Private blockchains process transactions more quickly because they are speedier, more dependable, and have fewer users. They are modifiable by the editor and are less secure. Consortium and hybrid blockchains were proposed to address the drawbacks of private and public blockchains. A permissioned blockchain known as a consortium blockchain is used when multiple organizations share data and conduct transactions. It is a kind of federated blockchain. It has a higher level of decentralized nature as well as security if we compare it with private blockchains. Permissioned and permissionless blockchains combined to provide a balance between control and freedom are known as hybrid blockchains. It has combined benefits of both public and private blockchains and can execute permissioned as well as permissionless features depending upon the need of the situation, Ex- IBM food trust [143]. Controlling authorities have the option to make the transactions transparent or to keep them open to the public. These blockchains can function based on the circumstances, such as when data exchange between hospitals or within the hospital is necessary.

B. EXISTING LITERATURE STUDIES

Literature review studies based on blockchain, healthcare and supply chain related have been done before. According to the existing literature, there has been a lack of case studies and use cases due to technology's novelty and complexity. There is a dearth of comparative studies showing the similarities and differences that different healthcare firms faced while adopting blockchain technology. More theoretical studies have been there and there is a lack of empirically validated studies across different geographical locations, especially developing countries. Blockchain applications like EHR management have been explored well while other applications still need exploration. A comparative study of how this study is different from other recent review studies conducted in this field is shown in table A1 in annexure.

III. RESEARCH METHODOLOGY

Petticrew and Roberts [146] has explained about eight different types of literature reviews: systematic, conceptual,

narrative, realistic, rapid, expert, critical and state of the art. Out of which, Systematic literature review (SLR) is the review technique that has been adopted for this study. According to [148], "a systematic literature review is undertaking specific research questions and answering them in a transparent and organized manner with reproducible actions at every step of the procedure." Some of the advantages of this technique include reduction of large amount of information, integration of critical information, eases findings generalizability, helps in systematic assessment of relationships among variables, increases statistical power in quantitative synthesis, improve accuracy and allow verification of procedures and methods. This paper adopted a stringent research protocol to minimize the extent of the researcher's bias. This work has been conducted in two phases. The first phase consists of searching for articles from scholarly databases using appropriate keyword pairs, sorting them out based on inclusion and exclusion criteria, and using bibliometric analysis to classify the articles with the help of VOS viewer software [150], [152]. Using content analysis and descriptive analysis—both of which are covered in the findings section—a thorough examination of the included articles is conducted in the second phase to address the research questions. The approved study protocol is depicted in Figure 1, and table A2 in the appendix provides the inclusion and exclusion criteria. The following parts provide a detailed explanation of the research technique that was adopted:

A. KEYWORD SELECTION

Different keyword pairs were used to search the relevant articles. Each pair generally contained '*blockchain*' and '*supply chain*' and '*healthcare**'. '*Healthcare**' was alternatively used with '*medical*', '*smart healthcare'*, '*e-health*', '*pharmaceutical*', '*healthcare management'*, '*healthcare service'* and '*healthcare system'* to avoid false negatives and complete the search criteria: *blockchain* AND *supply chain* AND *healthcare**; *blockchain* AND *supply chain* AND *medical*; *blockchain* AND *supply chain* AND *smart healthcare*; *blockchain* AND *supply chain* AND *e-health*; *blockchain* AND *supply chain* AND *pharmaceutical*; *blockchain* AND *supply chain* AND *healthcare management*; *blockchain* AND *supply chain* AND *healthcare service*; *blockchain* AND *supply chain* AND *healthcare system*.

B. DATABASE SEARCH

Seven scholarly databases were utilized to collect relevant articles from the systematic database search: Scopus, Web of Science, Science Direct, IEEE Xplore, EBSCO, Taylor and Francis, and Springer. Most of the relevant articles were obtained from the Scopus database. EBSCO offers access to other twenty-six databases like MEDLINE, Cochrane, and PsycINFO. IEEE Xplore has a strategic inclination towards blockchain and healthcare. Other databases like Web of Science, Taylor and Francis, Science Direct, and Springer completed the systematic search and ensured no relevant article was missed.

C. SCREENING PROCESS

The keyword pairs were used to find 2,438 articles in seven academic databases. 1178 duplicate articles were then eliminated once these items were de-duplicated. 1260 articles that were left were evaluated for their titles, abstracts, and keywords. The further selected articles were then conditioned to inclusion and exclusion criteria, as shown in the annexure table-A1. Only journals as sources and articles and review papers as documents were considered for the study. Exclusion criteria included studies that were not completely available, too technical, not scientific, or written in a language other than English. Conference papers, book chapters, white papers, theses, etc. were not included in the study. All these constraints lead to the removal of 876 articles. A full-text assessment of the refined 384 articles from the previous step was made to check whether they were related to blockchain, supply chain, or healthcare domain with 'blockchain in healthcare as the focus of research'. This process yielded 178 articles which were further subjected to bibliographic coupling analysis using VOS viewer software version 1.6.15 [150], [152]. Finally, 123 articles were included in our study, grouped into five clusters, through bibliographic coupling analysis. A detailed study of these 123 articles was performed, and the articles were analyzed concerning their respective clusters for identifying status, future avenues, and emerging areas concerning blockchain use in healthcare supply chains with the help of descriptive and content analysis.

IV. FINDINGS

This unit presents the outcomes of the study in terms of descriptive analysis as well as content analysis. With descriptive analysis, we aim to show the distribution of articles year-wise, journal wise, country wise and author wise. This will help us to understand the yearly publication trend, journals, countries, and authors with the most no. of publications in this field. With content analysis, we portray the interpretation of the content of the 123 research articles extracted through this review. The content analysis has been performed in two ways, firstly, by categorizing these articles into five clusters based on bibliographic analysis and discussing them further. Secondly, categorizing these articles based on the type of methodology used. This has been explained well in further detail-

A. DESCRIPTIVE ANALYSIS

It is the use of data to achieve initial insights and describe the main patterns, characteristics and trends within a dataset. This analysis focus on the data itself and does not present inferences beyond the data. This work shows the articles' year wise distribution, journal wise distribution, country wise distribution and author wise distribution below -

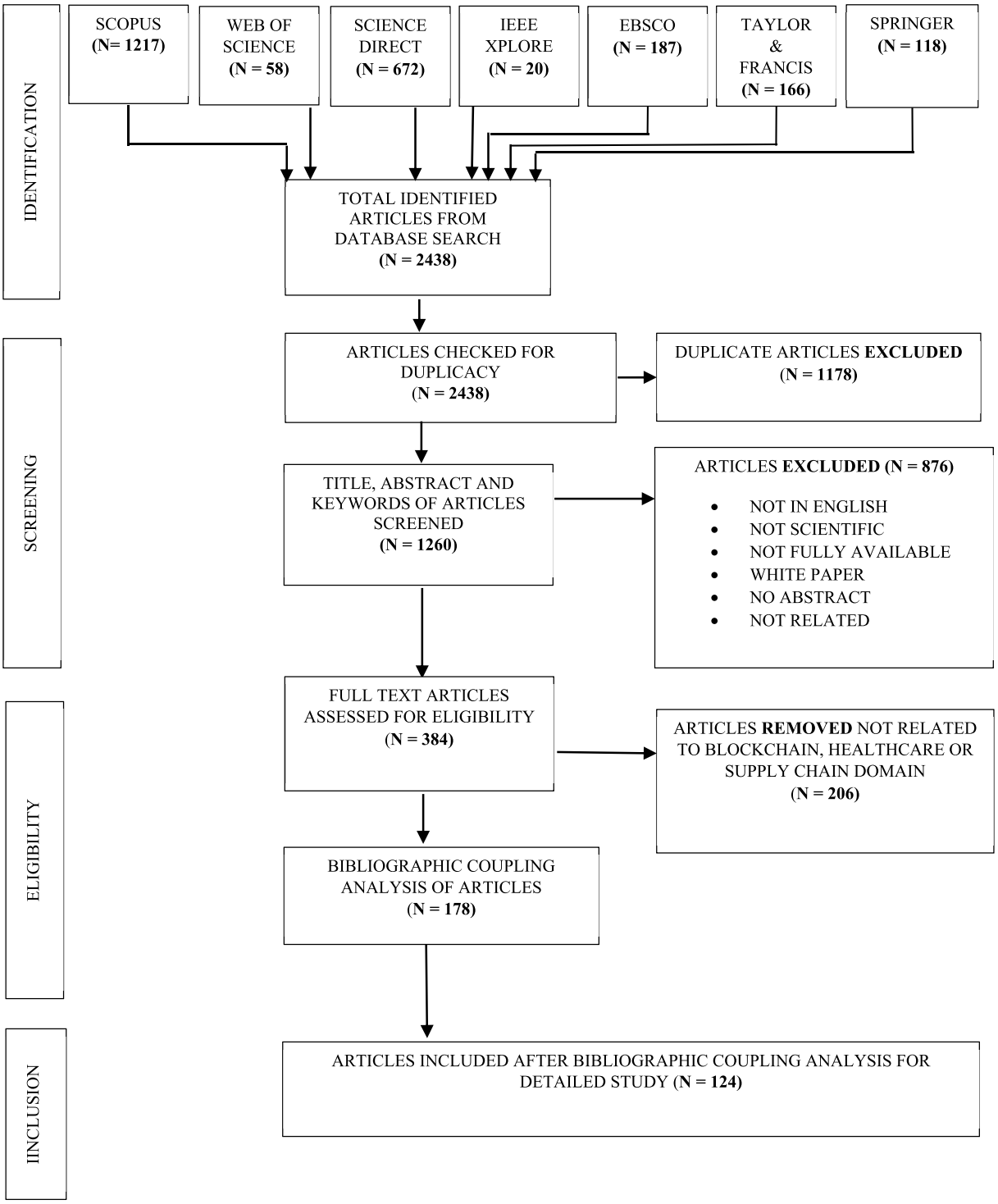

FIGURE 1. Structure of the systematic literature review process conducted.

1) YEAR WISE DISTRIBUTION OF ARTICLES

Figure 2 depicts that publications in this domain started in 2016. It has been steadily increasing till 2022 with more number of publications coming in 2023. This proves that more researchers are becoming interested in healthcare blockchain research, leading to an escalating number of publications.

2) JOURNAL WISE DISTRIBUTION OF ARTICLES

Figure 3 discusses the most relevant sources that has published at least 6 articles in this domain. IEEE Access has been producing the most number of journals in this area, followed by Sensors, Journal of Medical Internet Research, Electronics, etc.

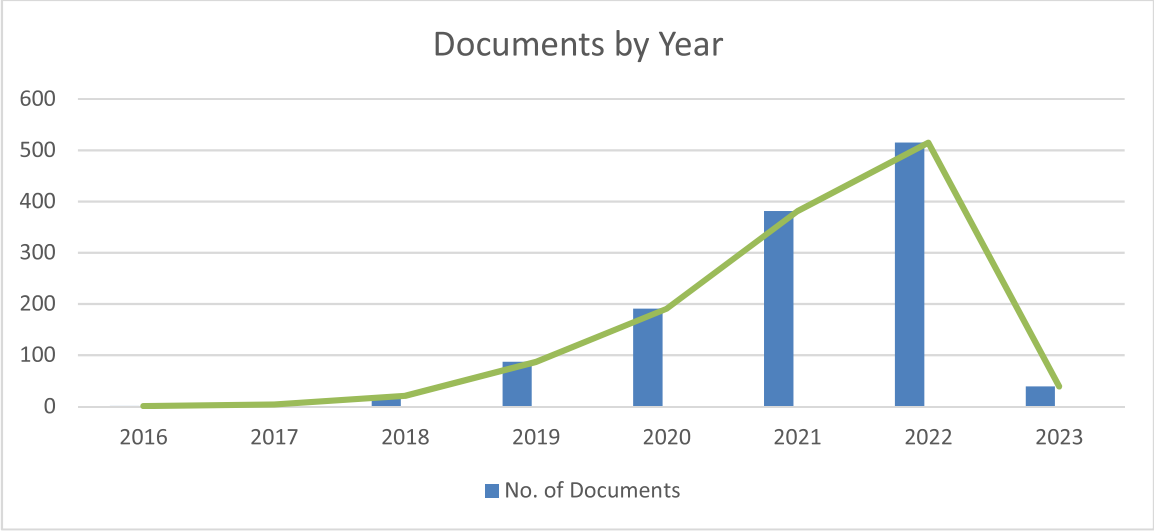

FIGURE 2. Documents by year.

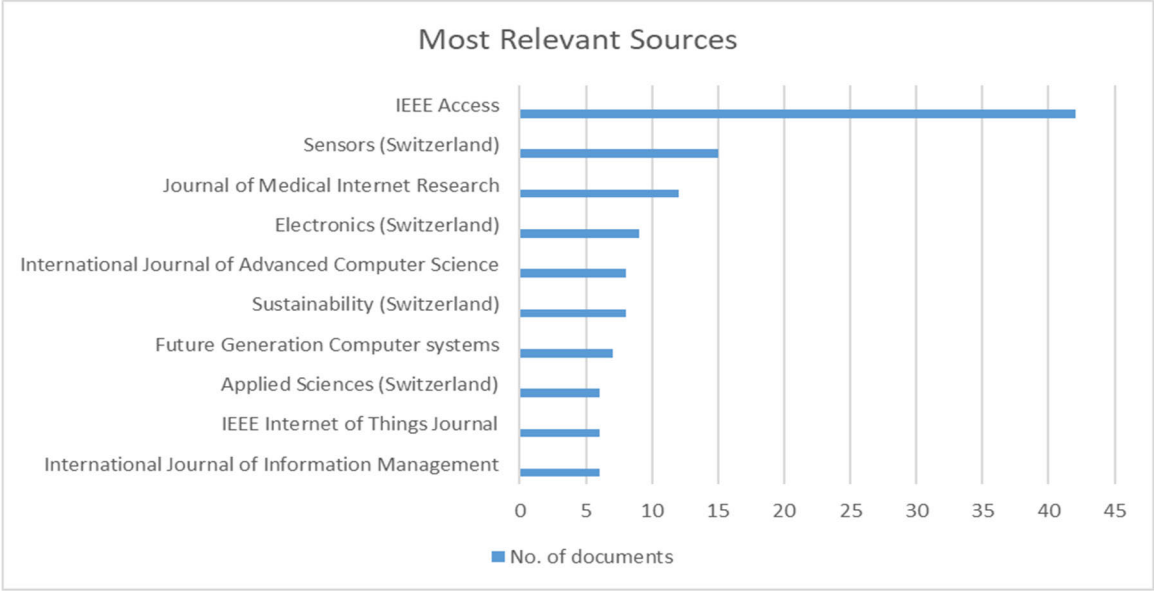

FIGURE 3. Most relevant sources.

3) COUNTRY WISE DISTRIBUTION OF ARTICLES

Figure 4 shows each country's contribution to publications in this domain. India tops the list, followed by the USA, UK, China, Saudi Arabia etc.

4) AUTHOR WISE DISTRIBUTION OF ARTICLES

Figure 5 indicates the most contributing authors with at least 7 publications in this domain. It presents Jayaraman, Salah and Javaid are the authors with the most no. of publications in this area.

B. CONTENT ANALYSIS

Under this unit, firstly, we argue the content of the papers divided into five clusters based on bibliographic analysis. Cluster 1 discuss about the issues, digitalization, sustainability practices and technology adoption in the healthcare supply chains. Cluster 2 further explains about the evolution and progress of blockchain technology and its integration with other technologies. Cluster 3 argues about the healthcare challenges, current status, emerging areas and implementation issues of blockchain technology in the healthcare sector. Cluster 4 further talks about the applications of blockchain technology in the healthcare sector. Cluster 5 discuss about the adoption status, analysis of factors for adoption, sustainability practices and applications of blockchain technology in supply chain management. Secondly, the article content is discussed based on the type of methodology used to categorise the articles in this study. The articles are classified into case study, literature review, MCDM, empirical study,

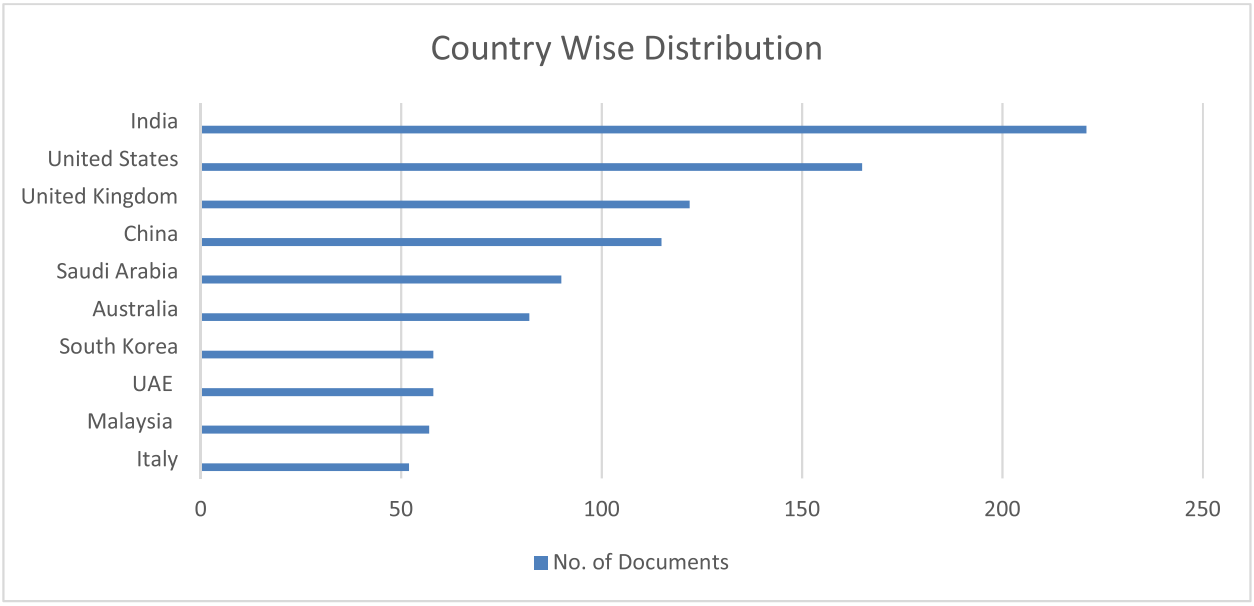

FIGURE 4. Documents produced by countries.

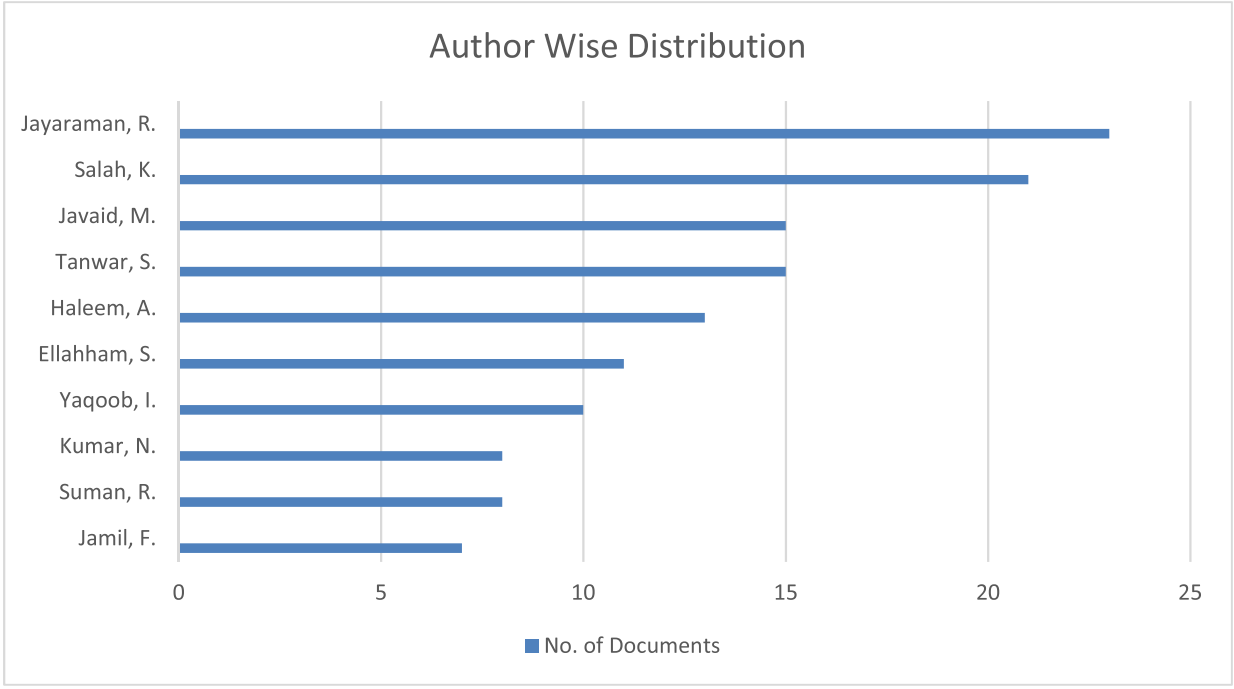

FIGURE 5. Documents published by authors.

mathematical model, hybrid study and proposed technology model. This has been further explained in the following sections –

1) ANALYSIS OF BIBLIOGRAPHIC COUPLING

Bibliographic coupling of documents with VOSviewer [150] is carried out to analyze the foremost research themes in blockchain, healthcare, and supply chain. This helps in analyzing all the articles regardless of the number of citations they possess. It prevents the exclusion of uncited articles, especially the recently published ones, which can prove quite relevant for the study. A minimum of two articles per cluster is attributed to this process. A total of 120 articles are grouped into five clusters based on bibliographic coupling, as shown in figure 6. The framework that we achieved after analysing the clusters have been shown in fig. 7.

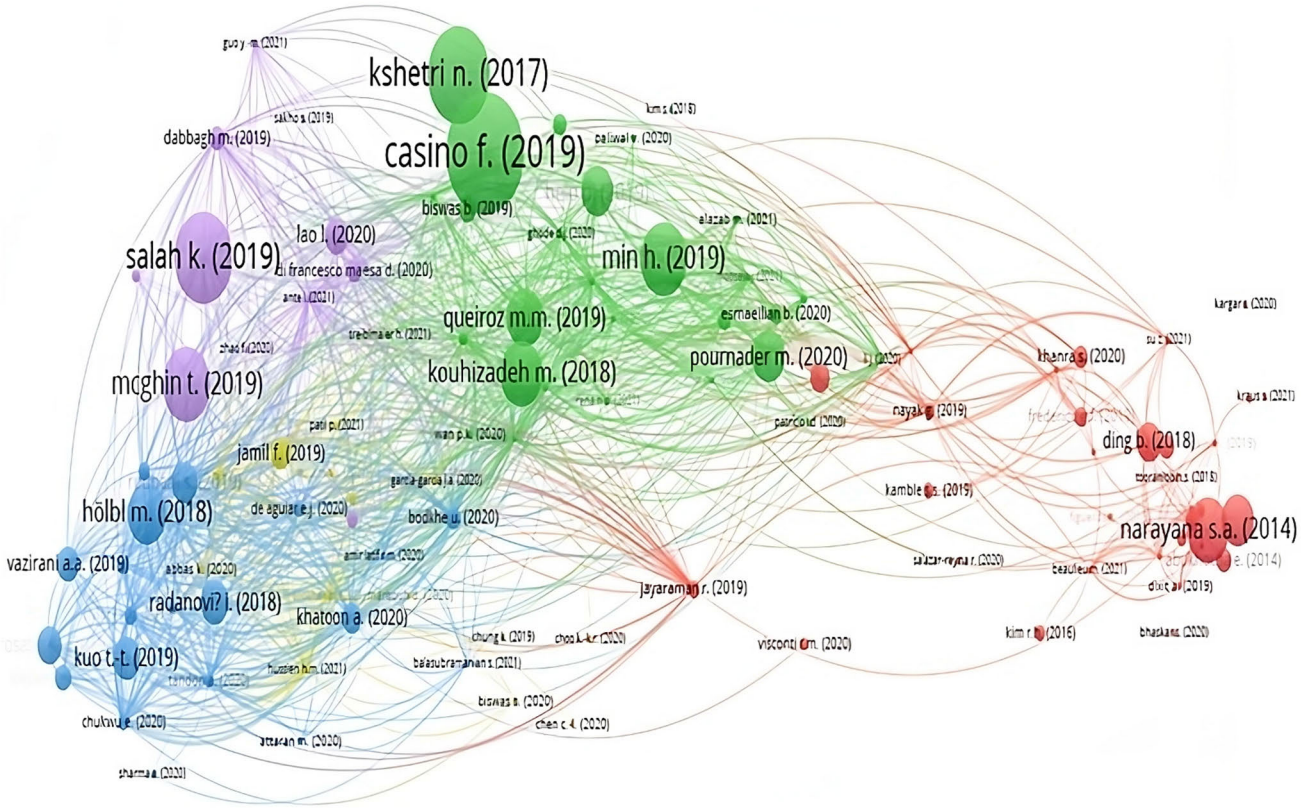

FIGURE 6. Bibliographic coupling analysis of involved documents.

a: CLUSTER 1: ISSUES, DIGITALIZATION, SUSTAINABILITY PRACTICES AND TECHNOLOGY ADOPTION IN HEALTHCARE SUPPLY CHAINS

Thirty articles contribute to this group to better understanding of research status in healthcare supply chains. Few studies discuss the issues faced by healthcare supply chains. Some publications argue that the healthcare industry must go digital and adopt Industry 4.0 technologies. Only a few studies address the new developments in pharmaceutical supply chains and the sustainability of technology adoption.

i) Healthcare supply chain issues:

Abukhousa et al. [2] discuss the need to improve the decision-making of healthcare supply chains through simulation and modeling. The authors propose simulation models for various healthcare supply chain issues like optimization of drug inventory, supply chain logistics, sterilization logistics, etc. They discuss adoption challenges such as implementation cost, complexity, and applicability of simulation and modeling techniques to healthcare supply chain problems and suggest which emerging technologies will support simulation and modeling in the healthcare supply chains.

Dong et al. [34] study the potential issues and relevant areas of healthcare supply chains that need improvement. Analysis of areas like inventory management, information technology use, performance analysis, supply chain operations, and lean and agile operations has been done before. More focus should be paid to healthcare-related issues such risk management, cold chain management, employee training, waste management, visibility and tracking of medications, and human resource practices.

Jayaraman et al. [59] discuss healthcare product management challenges like product recalls, counterfeits, expiration, and item shortages and suggest using IoT-blockchain-based solutions to address them. Blockchain and IoT are emerging technologies, but smart contracts applications can help overcome healthcare supply chain issues.

Kritchanchai et al. [69] explore information and material flows across various entities of healthcare supply chains at macro and micro levels. The micro level method is an exploratory case study with the hospital as the focal point, while the literature on supply chain management and logistics in the healthcare sector is assessed via a macro level analysis. The authors conclude that both the business and supply chain layers of the healthcare supply chain can achieve efficiency. The organizations' main concerns are patient safety and process efficiency at both levels.

Bhaskar et al. [15] identify the main problems with the healthcare supply chains in response to COVID, i.e., low initial supplies, sudden demand rise, low supply from the suppliers' side, and trust breakdown among stakeholders propose a framework to deal with the shortages. The authors report that the lean method of healthcare models is inappropriate

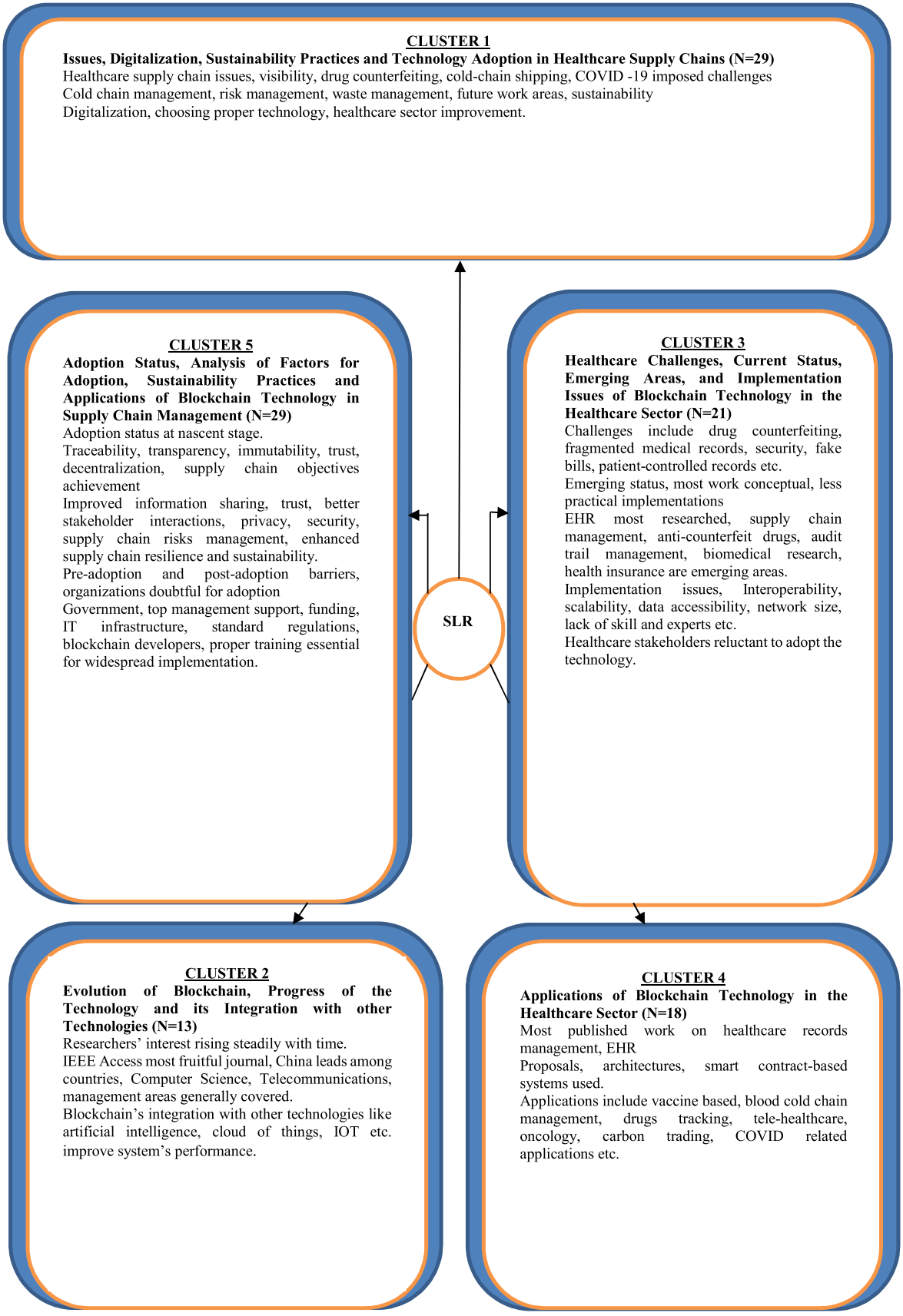

FIGURE 7. Framework for analyzing the systematic literature review (SLR).

and can compromise both public health and national security. In addition to public health measures like travel restrictions, comprehensive testing, and worker protection, a robust supply chain is required to prevent the pandemic. The supply chain becomes more efficient when blockchain technology is used.

ii) Parameter's influence on performance, technology adoption and digitization of healthcare supply chains:

Yoon et al. [131] study the impact of supply chain innovation and innovation leadership on supply chain efficiency with attention to hospital size. Both innovation leadership and supply chain innovation positively impact supply chain efficiency for hospitals with more than five hundred beds and other hospitals. The relationship varies. Supply chain innovation helps improve healthcare operations management, thus impacting organizational performance. Extracting required information from end customers and linking it through IT systems helps improve supply chain efficiency.

Kim et al. [63] conducted a review on healthcare quality focusing on technological and managerial innovation. The authors present diverse views of the pharmaceutical industry, hospitals, health insurance providers, and researchers worldwide on innovation and healthcare quality. The perspectives of healthcare policymakers and the empowerment of healthcare consumers are necessary to manage healthcare quality better and improve healthcare services.

Mandal and Jha [79] explore the importance of the collaborative asset in healthcare supply chains with respect to hospital supplier integration. The resources include group decision-making, planning, and implementation. Hospital supplier integration is positively influenced by all three of these dominating forces. Integration of hospital suppliers has a favorable effect on operational effectiveness. Mandal [78] demonstrates a positive relationship between human capital and the agility and performance of the healthcare supply chain. The author also demonstrates how IT capabilities improve human capital and healthcare supply chain performance.

Bradley et al. [19] assess the impact of using RFID and EDI jointly on hospital performance. The results show that the hospitals using RFID and EDI must bear lower supply costs, thus boosting supply chain cost efficiency. They are also linked with lower personnel expenses with time, leading to a rise in labor efficiency. No significant relationship is found between RFID-EDI use and hospital readmission rates.

Figueroa et al. [42] implement attribute-based access control model in RFID based on blockchain technology in healthcare. An access control system avoids healthcare assets entering the wrong area due to external risk or human error. Blockchain solves the financial, technical, privacy and security challenges of RFID, thus acting as an asset for healthcare environment when combined.

Alrahbi et al. [8] explore the drivers for technology adoption in healthcare systems of UAE using AHP. Using stakeholder theory, the authors ascertain what drives patients, staff members, UAE nationals, and foresight specialists to make the necessary adoption. Government assistance, infrastructure, information exchange, lean and green management, the environment both inside and outside the company, and social sustainability rank among the top considerations.

Frederico et al. [43] propose a conceptual framework because of studying industry 4.0 in the context of supply chains through a systematic literature review. The framework is based on four constructs i.e., technology levers, strategic outcomes, performance requirements and managerial and capability supporters. The proposed framework increases the stakeholders' interest and helps interested businesses in better exploration of supply chain 4.0 concepts.

Tortorella et al. [117] assess the adoption of healthcare 4.0 technologies on hospitals' performance and identify associated barriers for implementation. The implementation and maturity level of healthcare 4.0 vary considerably across the hospitals analyzed. The technologies positively impact hospital performance and their interaction with barriers are analyzed to understand the influence on hospitals.

Gupta et al. [47] identify supply chain performance drivers based on digitization technologies and prioritize them using Best Worst Method. The most relevant drivers found in the study are tracking products, appropriate studies for technology selection, and big data adoption. Appropriate technology selection and implementation like industry 4.0, blockchain, etc., help top management bring substantial upgrading in the supply chain operation.

Visconti and Morea [122] discover that healthcare digitalization influences pay for performance incentives and project financing in smart hospitals. Many healthcare problems like paper data, last-mile unavailability, performance management, fewer diagnostic services etc. can be dealt with the help of digital investments that help achieve sustainability. Digital technologies help reduce congestion in hospitals, manage big data timely, and even be useful for disease observation in big pandemics like COVID.

Kraus et al. [68] present the state of digital transformation in the healthcare industry. The study classifies articles into five categories – patient-centered approach, healthcare organization's operational efficiency, workforce practice impact, organizational factors, and socio-economic aspects. Patient-centric approaches, meaningful use of digitalization technologies, and proper data management help adopt digital healthcare models and improve the whole healthcare process.

Beaulieu and Bentahar [14] stress the importance of the digitalization of healthcare supply chains to bring flexibility and improve efficiency. The authors propose initiatives for digitalization that assist managers in improving hospital supply chains. These initiatives' identification is based on four supports, i.e. (a) healthcare stock management, (b) medical supply management in operating rooms, (c) internal supply chain improvement, and (d) creating more dynamic logistic networks.

Hopkins [51] investigates emerging industry 4.0 technologies to improve supply chain performance through the perspective of supply chain practitioners. The study is based in the Australian context. Larger firms are more digitally prepared than smaller firms, and small investments with some of the technologies have a substantial impact.

iii) Pharmaceutical supply chains and sustainability improvement in healthcare supply chains:

Pedroso and Nakano [95] stress the importance of technical information flows in pharmaceutical supply chains and their significance in demand creation. Flows of technical information, financial, material, and order information need a proper alignment for the effective working of pharmaceutical supply chains, especially those whose success depends on timely delivery.

Narayana et al. [87] share insights from a systematic literature review of pharmaceutical supply chains from a managerial perspective. Earlier studies have used case studies, surveys, and mathematical modeling to examine various supply chain issues. Research interests have also shifted from pharmaceutical supply chains working in the manufacturing environment to the healthcare industry and fiscal entities.

According to Ding [33], potential hindrances to sustainability adoption in pharmaceutical supply chains include improper regulations, high time and cost involvement, less trained manpower, lack of coordination across the supply chain, poor customer awareness, etc. The author concludes that industry 4.0 based solutions can help overcome these barriers by enhancing the flexibility of drug supply chains, proper waste management at various stages, co-ordination improvement, and improving the supply chain managers' decision making.

Tooranloo et al. [116] study factors impacting sustainable electronic supply chains in healthcare establishments. Infrastructure and technology management are the two primary factors affecting the sustainability of electronic supply chains in the healthcare sector.

Duque-Uribe et al. [38] present a framework for identifying supply chain practices that can help improve hospitals' sustainable performance based on a systematic literature review. The framework comprises of management practices like leadership, strategic management, customer relationship management, supplier management etc. and can become a base for analyzing sustainable supply chain practices in hospitals.

Hussain et al. [52] share a structure to identify, categorize and prioritize social sustainability motivators in healthcare supply chains using AHP. The stakeholders' (employees, patients, government, and suppliers) views are taken to accomplish the study. Five categories comprise the motivators: innovation and technology, excellence and awards, attitude, media and reputation, and organizational practices.

Nayak et al. [88] propose a framework for blockchain technology adoption in small and medium enterprises in sustainable supply chain management. Managers can now view the adoption of blockchain in the supply chain more sustainably thanks to its benefits, which include improved communication between entities, access to confidential data, opportunities for improving performance outcomes, the creation of smart devices, etc. Future challenges include supply chain players' readiness, loss of private data, a lack of regulations, etc.

Dau et al. [29] propose a conceptual framework based on circular economy and corporate social responsibility mirror to assess the sustainable healthcare supply chains. The enhancement of sustainable healthcare supply chains and the shift from linear to circular models are facilitated by the convergence of industry 4.0, corporate social responsibility, and the triple bottom line.

Kargar et al. [61] develop a tri-integer linear programming model to design medical waste reverse supply chain. The three objective functions of the analysis are to minimize total cost, minimize medical waste and maximize the best waste treatment technology under sustainability conditions. A real case study is also conducted in the Babol area of Iran to validate the findings. Supply chain managers can act accordingly and make better strategic decisions with the results obtained.

Ghadge et al. [141] shared insights about blockchain and pharmaceutical supply chains nexus. While it has accelerated since COVID-19, blockchain-related research in pharmaceutical supply chains is still advancing slowly when compared to other industries.

b: CLUSTER 2: EVOLUTION OF BLOCKCHAIN, PROGRESS OF THE TECHNOLOGY AND ITS INTEGRATION WITH OTHER TECHNOLOGIES

This cluster of thirteen articles sheds light on how blockchain technology has progressed, how it has progressed through the years, and what benefits the technology can attain by integrating other technologies.

i) The evolution and progress of blockchain technology:

Dabbagh et al. [28] present a bibliometric analysis of the evolution of blockchain. A continuous rise is seen in the publication trends of blockchain over the recent years. Computer science is the subject of most articles, with engineering, telecommunications, and business sectors following. The blockchain's biggest number of articles with the highest total amount of citations belongs to IEEE Access.

Zheng et al. [135] study blockchain progress from the performance and security perspective. Blockchain's features like transparency, decentralization, security, and privacy are useful in many industrial applications. The authors discuss the performance metrics, architectural choices, database management, and hybrid blockchains to maintain a balance between performance and security aspects. Many issues like parallelism, DDoS protection, cryptography, consensus protocols, and privacy need to be sorted out.

Sakho et al. [104] present perspectives and issues related to blockchain technology. The blockchain features, such as safe, reliable, decentralized, transparent, and open, make the technology highly useful. It is being prominently used in banking, insurance, healthcare, and the supply chain.

Guo et al. [46] focus on current blockchain topics using bibliometric analysis. The blockchain study includes aspects of computer science, electronics and electrical engineering, industrial engineering, energy fuels, and telecommunications. China leads among countries, followed by the USA, England, and India, with Beijing University of Posts and Telecommunications as the most productive institute for contributing to this field. According to the authors, smart contracts, bitcoin, Ethereum, security, and cryptography are blockchain-based hot research topics. Management, energy, blockchain technology, smart home, and machine learning are the directions that need further investigation.

The current state of smart contract research is given by Ante [10], who also identifies some of the major themes. Smart contract usage has increased recently, primarily in relation to Ethereum and Hyperledger's blockchain architecture. The foundations and development, standardization, security, integration with blockchain technology and the Internet of Things, as well as the promise and problems of smart contracts, are among the categories in which research on the subject is divided. Although smart contracts are still in their infancy, as technology advances, more industries will find use for them.

Choo et al. [25] share management and technical opportunities and challenges for blockchain systems to face. The authors explore management areas of supply chain and logistics, decision support systems, Fintech etc., and technical areas like IoT, smart cities, healthcare, building blocks, security, privacy etc. The management-related developments and challenges have been acknowledged, but technical ones need more investigation.

Di Francesco Maesa and Mori [31] study blockchain applications other than cryptocurrency. The authors analyze various application scenarios such as electronic voting, identity management, healthcare record management, decentralized notary, access control system, and supply chain management and propose blockchain-based solutions. Various applications of blockchain technology show a profound interest in the technology that will rise as the technology achieves maturity.

Garcia-Garcia et al. [44] present a systematic literature review about business process management in the blockchain domain. The majority of research done in this field are process implementation and execution. Others are process modeling and analysis related. Most of the proposals are conceptual or theoretical in specific supply chain or industrial processes with no methodologies to support them.

ii) Blockchain's integration with other technologies:

Salah et al. [105] talk about blockchain technology and artificial intelligence integration. Blockchain offers decentralization, security, and trust among users and facilitates interaction among users without any third-party involvement, whereas artificial intelligence offers intelligence and decision-making capabilities machines as humans. The combined use of both the technologies can be used in healthcare for safe and secure data sharing and management, can improve biomedical analysis, and the technology-controlled robots can be used for healthcare assistance.

Abbas et al. [1] propose a drug supply chain management and recommendation system based on blockchain and machine learning. Using Hyperledger Fabric, the blockchain-based pharma supply chain management system continuously records and monitors medications, whereas the machine learning-based system recommends best-rated drugs to consumers. This framework helps pharmaceutical companies tackle the problem of counterfeit medicines and boost their business.

Nguyen et al. [89] study blockchain's integration with Cloud of Things. Cloud of Things provides flexibility and scalability to increase blockchain's operational efficiency, and blockchain helps address Cloud of Things issues including network security, decentralization, and data privacy. This integrated technology has various applications and can improve data storage sharing and service management in smart healthcare.

Lao et al. [73] shed light on IoT-blockchain combined use. Many IoT applications like digital payments, smart contracts, and data storage adopt blockchain for improved performance. Challenges to adopting blockchain in IoT systems are resource constraints due to the mismatch between blockchain and IoT requirements and system scalability. Many companies are trying to combine this integrated technology with their business models for profit enhancement.

Patil et al. [93] describe blockchain-based IoT access control methods and applications in the healthcare and supply chain. Blockchain and IoT connect concerned stakeholders like patients, doctors, pharmacists, etc., and maintain a smart and secure healthcare system. The integrated applications of blockchain and IoT can help with real-time data recording, better tracking of products, and maintaining quality control in supply chains.

c: CLUSTER 3: HEALTHCARE CHALLENGES, CURRENT STATUS, EMERGING AREAS, AND IMPLEMENTATION ISSUES OF BLOCKCHAIN TECHNOLOGY IN THE HEALTHCARE SECTOR

In this cluster, twenty-three studies add to the literature regarding the present scenario of research and adoption of blockchain technology in the healthcare domain. Few articles discuss healthcare challenges and the blockchain features that help resolve them. Limited studies present healthcare stakeholders' views about blockchain and their problems in this sector. Some articles propose current areas of focus of researchers and managers and the emerging areas which can be worked upon in this area. Blockchain limitations, type of consensus algorithm, blockchain mainly used, and benefits of this technology in the healthcare sector are also debated.

The research state of blockchain applications in healthcare is presented by Holbl et al. [50]. Blockchain is still in its infancy and has just lately made its way into the medical field. In this topic, most of the research has been done on

data exchange, access control, and electronic health records. The following topics can be researched in the future: medical billing, supply chain management, audit trail management, and medicine counterfeit prevention.

Radanovic and Likic [99] share the prospects of using blockchain technology in medicine. Blockchain is an advancing technology that is currently immature but greatly benefits the healthcare sector regarding data safety, accessibility, and cost savings.

Drosatos and Kaldoudi [36] review applications of blockchain technology in the biomedical sector. The research mainly focuses on access control and integration of electronic health records and medical data. Different blockchain types may have their applicability for different biomedical applications, but the authors suggest consortium blockchain as the most practical solution as it provides both efficiency and immutability at a low cost.

According to Mcghin et al. [82], blockchain applications are mostly employed in the medical field. The most extensively studied uses of blockchain technology include availability, integrity, security, decentralization, and authentication. The authors argue that healthcare needs are a subset of blockchain features and present blockchain solutions that support patient-controlled healthcare data sharing, such as Gem Health Network, OmniPHR, MedRec, MeDshare, etc.

Vazirani et al. [121] study the feasibility of blockchain for healthcare record management through a systematic literature review. Most studies discuss potential benefits and drawbacks without any evaluation of their usefulness. Only a few practical implementations are performed. Appropriate standards and suitable guidelines can improve interoperability without compromising the privacy and security of patients.

Shuaib et al. [112] analyze the blockchain consideration for healthcare information systems. Blockchain benefits healthcare systems by providing better sharing of medical information and its security, improving audit access, managing pharmaceutical supply chains, and storing both on-chain and off-chain data. Researchers focus on fraud detection, improvement of EMR systems, privacy, and security considerations, and blockchain's integration with other technologies like IoT when considering blockchain for healthcare systems.

Rouhani and Deters [102] discuss smart contracts' security, applications, and performance aspects for blockchain applications. Smart contract is a programmable section of blockchain that accomplishes complex tasks automatically and is stored on the blockchain network. Resource sharing, record management, and access control are the areas where smart contracts contribute significantly to healthcare, IoT, and the supply chain.

Yaqoob et al. [128] present blockchain use in healthcare considering the stakeholders' views and issues they face. Different stakeholders like healthcare providers, patients, insurance payers, research organizations, and pharmaceutical supply chain entities face various issues of EMR installation, fragmented patient records, need for patient control medical records, fake bills, drug counterfeiting, etc. Blockchain-based systems face challenges after their adoption in healthcare, including scalability, 51% attack, environmental sustainability, confidentiality, anonymity, and data privacy issues.

Blockchain applications in healthcare are systematically reviewed by Chukwu and Garg [26]. Blockchain use in healthcare is getting attention and investigation, but most of the published work in this area is conceptual in nature and includes framework proposals and experimental prototypes. Further investigations into the technology's actual application in real-world settings are required. Blockchain addresses concerns with trust, security, and privacy while maintaining storage costs and necessary performance.

De Aguiar et al. [4] survey strategies based on blockchain for healthcare. Blockchain in healthcare is a recent concept, and its applications started gaining popularity in 2016. Early applications of this technology included sharing medical records, managing the supply chain for medications, and remote patient monitoring. Due to their ease of adoption on platforms like Hyperledger and Ethereum, Proof-of-Work and Practical Byzantine Fault Tolerance (PBFT) are the consensus protocols most utilized for blockchain-supported healthcare applications.

Attaran [12] studied the role of blockchain technology's implementation in healthcare industries, challenges to face, and opportunities created. Blockchain's transparency, immutability, decentralization, and suitability help reduce operational costs, improve data integrity, access control and help in interoperability and provenance of medical items. The technology helps collect data from several providers, facilitates secure communication between healthcare providers and patients, and improves public health management.

Bodkhe et al. [18] analyze the applicability of blockchain solutions for Industry 4.0 applications. Systems presently using blockchain applications in healthcare include MedRec, MedShare, EHR, etc. Logistics comprise RFID systems, food traceability systems, and performance systems in the supply chain. The authors discuss open healthcare issues like patient data management, main patient indices, clinical trials, data provenance and integrity, data enrichment, and drug traceability and suggest using blockchain and industry 4.0 applications to solve them. Supply chain issues like counterfeiting, authenticity, provenance tracking, and inefficiency deserve attention, and blockchain significantly impacts these problems.

Zarour et al. [133] evaluate the effectiveness of blockchain models for healthcare information sharing. The authors collected data from healthcare experts and used the Fuzzy Analytical Network Process and TOPSIS. The criteria taken for evaluation include patient identity, data monitoring, consensus, value, immutability, and data security. Healthcare data may be shared on the most reliable, secure, and efficient platform—the private blockchain model.

Sharma et al. [109] highlight the potential of blockchain technology to fight against the corona virus pandemic.

Blockchain technology can be utilized for disease control, outbreak and donation tracking, strengthen medical supply chains, bring traceability to operations, help track medical types of equipment, patient information sharing, and improve the transparency of infected patients' treatment that helps in better recovery.

Kalla et al. [60] evaluate blockchain's role in the COVID-19 pandemic. Numerous challenges are confronted during the pandemic, such as social distancing, fake information flow, maintaining continuity of essential government services, charity, and funding distribution, keeping an efficient supply of medicines and medical equipment, patient information sharing, hampered food distribution, and education and suggest blockchain's use for tackling them.

Tandon et al. [115] review blockchain's prospective in healthcare. The obtained themes from the review are classified into data management, efficiency enhancement, technology advancement, and conceptual evolution.

Biswas et al. [17] focus on the healthcare sector and explore how blockchain can benefit these industries. Blockchain is an efficient and reliable solution for many problems like security, accountability, privacy, etc., which healthcare systems face today. Off-chain storage and big data management need careful consideration while applying blockchain to healthcare systems.

Rejeb et al. [101] share insights about the ongoing blockchain research in healthcare. The most prominent journals in this discipline are IEEE Access, Journal of Medical Systems, Journal of Medical Internet Research, Sensors, and Electronics. In this regard, China and the United States of America have contributed the most, followed by India and England.

Hussien et al. [53] study blockchain's usage in the healthcare industry. The authors propose decentralization, transparency, security, and privacy as motivations for adopting blockchain technology in healthcare industries. The obstacles that are likely to develop throughout the adoption of technology include scalability and storage capacity concerns, blockchain size issues, skill issues, universal interoperability, and standardization issues. These issues must be resolved in an efficient manner for the technology to be widely used. Health data sharing, counterfeit drugs, and transparency in clinical trials are the prospects that need further investigation.

Balasubramanian et al. [13] propose a readiness assessment framework for blockchain adoption in UAE healthcare systems. Key stakeholders like government, business entities, patients, and healthcare providers' views are considered, and their readiness to collaborate is presented. Larger firms are more eager to explore blockchain benefits.

Tortorella et al. [118] assess and prioritize the implementation of healthcare 4.0 in hospitals with the help of quality function deployment. Digital integration within healthcare establishments is limited to specific sectors, departments, or processes. The common problems in both studies are lack of supply chain education, association and incorporation, mismatch between demand and supply, and improper data investigation to support decisions.

Ramzan et al. [147] present a literature review of blockchain applications in healthcare. The study's conclusions indicate that it is primarily used for EHRs, access control, and data sharing; management of prescription drugs is a rare application for it.

Merlo et al. [144] examine the condition of BT research in the medical field now. The authors emphasized that current research focuses on using blockchain technology to establish electronic health records and secure data. Unexplored are other avenues, like the integration of BT with other new technologies.

d: CLUSTER 4: APPLICATIONS OF BLOCKCHAIN TECHNOLOGY IN THE HEALTHCARE SECTOR

These twenty-one articles' authors examine the various applications of blockchain technology in the healthcare sector. Electronic medical records, the medication and blood supply chains, vaccine-based applications, specialty applications like telemedicine and oncology, and other applications like Covid and carbon trading are all covered by these applications.

i) Healthcare data and electronic medical record based blockchain applications:

Kleinaki et al. [65] present a notarization service based on blockchain confirming medical database queries and their respective results using smart contracts. The proposed architecture maintains data integrity, database non-repudiation, and data versioning. The service ensures that no modification can be made to data, and the database provides validation of the query made and its outcome after retrieval.

Ismail et al. [56] propose a lightweight architecture based on blockchain to improve healthcare data management. The architecture's performance is evaluated and compared with the bitcoin network. The architecture reduces the communication and computational processes compared to the bitcoin network, thus improving transaction throughput, and reducing scalability and energy consumption.

For the management of health log data, Chung and Jung [27] suggest using a knowledge-based blockchain network. Mobile data management services make use of IoT, wearables, sensors, medical equipment, and devices. The suggested approach preserves user health log data and records, and side chains enable extensive data storage with sufficient security and storage capacity.

Based on blockchain technology, Khatoon [62] created a smart contract system for the management of medical data. The recommended approach let patients exchange their medical records with doctors, researchers, and other relevant parties while maintaining the confidentiality and privacy of the shared data.

Latif et al. [9] propose a blockchain-based healthcare framework for improving medical treatment efficiency. The framework helps doctors prescribe the right medicines

concerning the patients' history. The record is updated, and a copy of that is sent to other hospitals so that the patient does not need to carry required documents if he refers to other hospitals.

Chen et al. [23] present an Electronic Medical Record sharing system among hospitals based on blockchain. The proposed architecture provides non-repudiation, data integrity, resistance to replay attack, forward and backward secrecy, and user untraceability that reduce the associated time and cost of repeated tests and wastage of medical resources.

Sookhak et al. [113] discuss blockchain and smart contract applications in healthcare, focusing on Electronic Health Record access control. Smart contract is the principal section of many blockchain applications and access control methods. In permissionless blockchains, access control is centered on predefined policies based on intelligent contracts, whose examples are MedRec and BHEEM. Attribute revocation, scalability, latency, and outsourced data privacy in Cloudchain are the current issues of EHR access control using blockchain.

ii) Blood, vaccine, and drug supply chain based blockchain applications:

Kim et al. [64] designed a cold blood chain system based on blockchain technology. The proposed design ensures visibility throughout the cold chain and avoids blood supply delays by reducing emergency blood transfer time. This, benefit hospitals away from blood banks.

Yong et al. [129] propose a blockchain-based vaccine supervision system. Smart contracts and blockchain technology can solve problems with the vaccine supply chain. The proposal helps in vaccine traceability and reduces vaccine-related fraud.

Jamil et al. [57] propose a blockchain-based drug supply chain integrity management in an innovative hospital. The model for safely managing drug supply chain accounts is built on top of Hyperledger Fabric. The tests performed on the system show that blockchain improves throughput and reduces system latency with minimum consumption of assets.

Pandey and Litoriya [91] propose a solution for stopping the circulation of counterfeit medicines based on blockchain. The suggested system makes sure that tax evaders do not misuse the rights intended for payees and verifies the legitimacy of the medications prescribed to the patients.

Musamih et al. [86] develop and verified a blockchain-based system for tracing drugs in healthcare supply chains. The model is Ethereum-based, using smart contracts and off-chain storage to track drugs. The outcomes of the tests on the model show that the architecture is cost-efficient, less energy is spent to drive smart contracts, and reliable in safety aspects.

Musamih et al. [145] propose a blockchain based solution for COVID-19 vaccine waste reduction due to underutilization and overproduction. The proposed solution ensures traceability, security, transparency, and trust with the use of smart contracts and was compared with existing solutions for validation.

iii) Blockchain applications for specific areas of healthcare:

Dubovitskaya et al. [37] share blockchain applications for data sharing in oncology. The technology helps in better data sharing and helps in optimizing pharmaceutical supply chains in oncology with the help of its features like traceability, transparency, and immutability. There is a lack of implementation of real-world models in oncology due to less interoperability, existing regulations, and the sensitive nature of healthcare data.

Ahmad et al. [5] discuss blockchain technology's role in telehealth and telemedicine. Blockchain can help overcome the centralized nature of telehealth services and can bring improvement in telehealth and telemedicine by offering transparent, secure, reliable, and decentralized remote healthcare services.

Bamakan et al. [139] discuss the applications and future trends of blockchain based waste management systems. The authors discuss how blockchain can help improve identification and tracking of waste generated in hospital environments.

iv) Miscellaneous applications of the technology in healthcare:

Hylock and Zeng [54] propose a patient centric framework, called healthchain, based on blockchain to address key barriers to blockchain adoption in healthcare. Challenges addressed by the framework include interoperability, data access, security, and scalability. Healthchain helps in maintaining complete and consistent healthcare records. The framework can be configured to improve security and speed.

Kuo et al. [72] introduce a comparative analysis of blockchain platforms and help choose a suitable platform for desired requirements. Ethereum, Hyperledger, and Multichain are among the most popular platforms. Most platforms possess similar features, but they have specific attributes like providing better security, privacy, or improved transaction speed.

Marbouh et al. [80] present and validate a trusted blockchain system to confirm COVID-19 data from various sources. The proposed structure can tackle problems of manipulation of data and miscommunication and can contribute to secure data tracking from external sources. The system is economically achievable and facilitates transparency, security, and data traceability among concerned stakeholders.

Zhao and Chan [134] propose a framework for blockchain planning in carbon trading. Blockchain improves efficiency and effectiveness and modifies the risk and cost configuration of carbon markets. The framework shows that blockchain shall be applied when the systematic risks are low, and the technology is mature enough. For commercial applications, a consortium blockchain and risk control and dispute resolving committee are well suited.

Erol et al. [140] share a case addressing the most feasible blockchain platform selection in the healthcare sector and used a novel MCDM framework comprising Analytic Hierarchy Process and Rough Compromise Programming.

e: CLUSTER 5: ADOPTION STATUS, ANALYSIS OF FACTORS FOR ADOPTION, SUSTAINABILITY PRACTICES AND APPLICATIONS OF BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN MANAGEMENT

The thirty-one studies in this cluster offer perceptive viewpoints on supply chain management applications of blockchain technology as it stands today. Most of the studies that are being given go over the adoption scenario that exists today and the variables that affect supply chains' implementation of new technologies. Some articles discuss the supply chain issues and blockchain's involvement in improving supply chain resilience, quality management, security, and privacy. There is a dearth of research on how the technology's adoption affects supply chains' sustainability and how it might be used for vaccination oversight and blood cold chain management. A comparison table of the studies in cluster 1 has been shown in table A3 of annexure.

i) Blockchain technology's potential, adoption status and its integration with supply chains:

Casino et al. [21] investigate the present status of blockchain technology across various sectors through a systematic literature review. The authors cover healthcare, supply chain, business, data management, privacy, IoT, etc. They suggest its high ability to alter the supply chain by bringing accountability, transparency, and flexibility to the networks. Proper choice of blockchain type and the associated processes are essential for the critical needs of different industries. As the technology's maturity rises, it is expected to penetrate deeper into other industries.

Queiroz et al. [97] study blockchain and supply chain integration and shed light on its applications. The integration is nascent and can bring disruptive improvements in supply chains. It will change business-to-business relationships as well as customer-to-business and customer-to-customer relationships. Industries like transportation, power, and healthcare utilize this integration and set a standard for other industries to adopt.

Pournader et al. [96] present applications of blockchain technology in supply chains, logistics, and transport through a systematic literature review. Literature is classified into trade, trust, technology, and transparency using co-citation analysis. In order to improve supply chain performance, blockchain technology must be integrated with the real world, which calls for the right instruments and technologies like the Internet of Things. Technology brings transparency to supply chains that improve traceability and sustainability.

Mubigmann et al. [85] throw light on the research status of blockchain technology in logistics and supply chain management using bibliometric analysis. In combination with blockchain technology, IoT fixes the infrastructural gap in data quality. Blockchain's decentralized consensus among the supply chain entities and automatizing the processes using intelligent contracts solve the traceability gap of supply chains.

Duque-Uribe et al. [38] observe many sectors like manufacturing, aviation, technology, finance, healthcare, etc., and present status and various insights about blockchain's implementation. Blockchain disrupts supply chains through proper data management, transparency, responsiveness, and operational efficiency improvement. Re-engineering of supply chains, supply chain resilience, sustainability adoption, and business process management are the booming areas of research interest.

Chang and Chen [22] explore the potential of blockchain technology and discuss its benefits and challenges concerning the supply chain domain. Blockchain upends supply chain operations while promoting automation, improved performance, and governance throughout the relevant processes. When utilizing blockchain technology in the supply chain, there are a number of crucial issues to consider, including transparency, traceability, stakeholder participation, and supply chain digitalization and integration. The authors recommend that future studies concentrate on supply chain integration, technology dissemination, and the social impacts of blockchain technology.

Kopyto et al. [66] present the current views of international experts on measuring blockchain technology's potential in supply chain management. The primary benefits of blockchain applications in the supply chain are efficiency and transparency, but two significant obstacles to adoption are data availability and validity. Supply chain management will be the main use of blockchain technology by 2035.; nevertheless, to properly guide and improve the views of those making decisions in this field, challenges must be adequately addressed.

Ali et al. [7] study blockchain technology's influence on various sectors through a systematic literature review. The impact is analyzed concerning three dimensions: benefits such as economic, strategic, organizational, technological, etc., challenges like environmental, adoption, operational, technological, etc., and functionalities corresponding to data ownership, protection of data, transaction processing, etc.

Moosavi et al. [84] review blockchain's role in the supply chain and identify how blockchain can contribute to this domain through a bibliometric analysis. Crucial blockchain areas where blockchain can contribute are finance, logistics, security, and supply chain management. The managerial benefits of the technology in supply chains include transparency in operations, asset tracking, reduced transaction cost, improved belief among supply chain entities, and fraud prevention. The empirical analysis is more minor in this field, and practical implementation will take considerable time.

Alkhudary et al. [137] investigate the supply chain disruption types that can be mitigated with the help of blockchain technology. The authors propose that blockchain technology

can only be used to alleviate certain supply and demand risks, such as operational risks, data loss, and counterfeit threats.

ii) Analysis of factors for adoption of blockchain technology in supply chains:

Biswas et al. [16] construct a framework for barrier analysis of blockchain technology adoption in industry and service sectors using the DEMATEL technique. The most persuasive obstacles are those related to market-based risks and scalability, whereas the most influential factors affecting the technology's effective adoption are bad economic practices and excessive sustainability costs.

Ozturk and Yildizbasi [90] identify barriers to blockchain technology implementation in supply chains. The barriers are classified into organizational, financial, technological and social factors. Blockchain supply chain integration is faster for less complicated supply chains, thus harder for sectors like logistics and healthcare as they form a complex network of information flow, product flow, and finance. The stakeholders need to be persuaded of the technology's benefits in eliminating resistance.

Choi et al. [24] analyze issues contributing to organization's resistance to blockchain adoption in supply chains. The obstacles are divided into three categories: organizational, environmental, and technology. Regulation constraints, technological maturity, implementation costs, compatibility, scalability, and complexity are the most essential factors.

Wong et al. [127] empirically analyze the factors for blockchain technology adoption in supply chain management. The intention to adopt blockchain technology is positively influenced by affinity, readiness for technology, and trust. Both intra- and inter-organizational integration are necessary for the seamless deployment of technology.

Queiroz et al. [98] examine blockchain adoption behavior in supply chain management in emerging economies. The study is empirically validated in terms of the Brazilian context. The most important factors promoting blockchain adoption are social influence, trust, facilitating conditions, and effort expectancy; performance expectancy has no bearing on adoption behavior.

Ghode et al. [45] present views on blockchain adoption by analyzing challenges using ISM. Transparency, governance, and immutability are identified as the most critical challenges and depend on the adoption process of blockchain in the supply chain. Managers may better plan the actions to remove obstacles in the way of blockchain adoption in the supply chain by taking into account the recognized issues and their interrelationships.

Gokalp et al. [136] investigate blockchain adoption determinants in supply chains concerning organizations' using AHP. Environment-related determinants are found to be more crucial than the organization or technology-related determinants. The most influential determinants include financial resources, top management support, and IT resources, impacting organizations' adoption decisions. Blockchain's integration with Customer Relationship Management or Enterprise Resource Planning deserves future attention to improve organization's efficiency.

Alazab et al. [6] examine factors impacting blockchain acceptance through empirical analysis. The authors examine methods to better understand supply chain blockchain adoption behaviour and offer suggestions for improvement. Blockchain adoption is found to be positively influenced by interorganizational trust and trust in technology, whereas adoption behaviour is not affected by social influence.

Rana et al. [100] identify challenges for blockchain adoption in the Indian public sector. Lack of validation and lack of standards are crucial barriers to the technology's adoption. Reluctance to use technology and technology's integration with other systems are the barriers that are highly dependent on other factors. The authors highlight the importance of examining the impact of standards, privacy, security, and lack of validation, as well as the reasons why organizations are reluctant to adopt new technologies.

Alzahrani et al. [138] identifies important factors and assesses its impact on blockchain adoption in healthcare organizations. The authors offer a research model for the same and validate it with two case studies.

Govindan et al. [142] identify and prioritize blockchain adoption barriers based on balanced scorecard perspective. The authors suggest that lack of government policies, financial issues, lack of knowledge and security issues are among the most important challenges to blockchain adoption.

Yadav et al. [149] explore the adoption barriers of vaccine supply chain utilizing TOE framework and DEMATEL. The results show that the most significant difficulty is the need for changes in organizational structure and policy and lack of technical expertise as the most impactful challenge.

A more detailed categorization of the challenges has been done in table A4 of the annexure.

iii) Blockchain's relevance for sustainable supply chain management:

Kouhizadeh et al. [67] present a synopsis of blockchain technology's potential in sustainable supply chains. The authors suggest a need for clarity between hope and hype for adopting blockchain for sustainable supply chains. Theoretical research and empirical investigations are required to evaluate technology's impact on sustainable supply chains to check whether the technology is suitable for social innovation, or it is of limited relevance for sustainable supply chains.

Paliwal et al. [92] review publications to inspect blockchain technology's contribution to sustainable supply chain management. The advantages of technology like data management, accessibility, decentralization, immutability etc., drive companies for blockchain adoption and promote sustainability. The disruptive role of technology in supply chains can improve sustainability practices which have become essential for business purposes.

Esmaeilian et al. [41] concise previous studies on the industry 4.0 applications used for sustainable supply chains. The review of blockchain's capability of sustainability

improvement is classified into four categories: tokenization and innovative mechanisms design for promoting green behavior, decreasing cost and increasing system efficiency, sustainability monitoring of supply chains, and visibility improvement across the product's lifecycle. The choice of technology and optimized business strategies help achieve sustainable development goals.

Joshi et al. [153] present a systematic literature review on blockchain's use for sustainable development. Scholarly emphasis focused on three research themes: ''business practice and economic sustainability,'' ''agriculture and food security,'' and ''business practice and environmental sustainability.'' Research gaps are categorized into four areas based on the synthesis and assessment of essential studies: theoretical underpinning, methodological limitations, research themes, and obstacles associated with implementing technology.

Difrancesco et al. [154] claim that blockchain improves supply networks that are sustainable. It was concluded that sourcing and manufacturing, inventory management, distribution and delivery, retail, customer experience, product returns, and reverse logistics are the six main supply chain activities for blockchain applications. The authors also covered how integrating blockchain technology into each link in the chain can improve supply chain performance. Based on the findings of a qualitative investigation, a theoretical framework for supply chain performance improvement using blockchain technology has been developed.

Wang et al. [155] assess stakeholder perspective for blockchain adoption in sustainable supply chains. The authors found 27 challenges for blockchain adoption through literature search and stakeholder perspectives. The results show that the five main barriers are unclear public data management regulations and disclosure practices, high integration costs, a lack of functional appeal, storage constraints, and a lack of financial incentives.

Mulligan et al. [156] provide insights to policymakers regarding blockchain's use for sustainable development through systematic literature review. The SLR demonstrates how blockchain has primarily impacted three aspects of sustainability: supply chains, energy systems, and enabling Internet of Things solutions like smart cities, which allow for the creation of peer-to-peer energy trading networks.

iv) Blockchain technology's impact and applications in supply chains:

Kshetri [70] evaluate blockchain's significance in providing security and privacy aspects to organisations. Blockchain's decentralized architecture provides solutions to IoT security problems that rely on centralized systems and track causes of insecurity in IoT-driven supply chains. Firms need blockchain implementation to strengthen IoT security in supply chains, which will be mandatory in such cases.

Attaran and Gunasekaran [11] discuss the blockchain's impact on industrial performance. To increase productivity and cut costs, The writers emphasize the advantages of blockchain technology., including decentralization, process integrity, value redundancy, shared control, and data security. The legislative framework, a lack of knowledge and confidence in technology, teamwork, sluggish bitcoin processing, and energy footprint are the barriers to the technology's broad use and removing them can help blockchain produce more.

Helo and Hao [49] review studies on blockchain technology in operations and supply chains and present the architecture of logistics monitoring systems based on blockchain. The reference architecture is tested in Ethereum and can be implemented in supply chains using the software. The blockchain architecture's automation, transparency, and trust in supply chains solve issues like managing multiple entities in the network, the need for a shared database, and transparent transactions.

Min [83] discusses blockchain technology's implementation to improve the supply chain's resilience. Supply chain risks come from a variety of sources, including technological, geographic, legal, financial, and social ones. These risks must be promptly mitigated, and expenses must be kept to a minimum. Due to its ability to lower the impact of supply chain interruptions, prevent hazards, increase operational flexibility, and improve stakeholder communication, blockchain technology plays a critical role in times of risk and uncertainty.

Wan et al. [125] explore blockchain technology's impact on information sharing in supply chains. Blockchain's decentralized architecture provides excellent transparency and traceability, thus promoting better information sharing. Blockchain empowered information-sharing benefits all supply chain members and increases collaboration among supply chains such as healthcare, manufacturing, etc.

Li et al. [74] study blockchain technology applications for optimizing supply chain quality management. Reliability of the data records decreased quality control cost, product traceability, and efficiency optimization benefit the framework. Challenges of blockchain framework for optimizing supply chain quality management include suppliers' information confidentiality, high initial investments, interoperability, scalability, incidental cost, and universality of the framework.

Patricio and Ferriera [94] research blockchain security using bibliographic coupling analysis. There is a need to provide the right balance between public access and privacy through blockchain and data protection from unknown elements. Blockchain's ensurance of features like transparency, security, traceability, and accuracy depends on smart contract execution.

Treiblmaier et al. [119] stress the need for cross-disciplinary studies on blockchain technology. Generally, studies on the blockchain are conducted in a technical or managerial manner, and other social, legal, and philosophical perspectives are not given much weight. Better technology exploration can bring more insights to discover the technology's true potential.

2) CATEGORIZATION OF ARTICLES

The studied articles have been divided into different categories such as case studies, literature reviews, MCDM work, empirical studies, mathematical-based studies, hybrid work used, and technology models, as shown in table 1. Literature review studies include reviews, systematic reviews, conceptual frameworks, discussions, and authors' perspectives presented. MCDM studies involve using various decision making techniques used in the study. Empirical studies include statistical techniques used, interviews, surveys, Delphi, and the use of focus groups. Mathematical-based studies involve the use of mathematical modeling. Hybrid work involves the use of two different techniques in the same study. Technology model studies include blockchain models proposed or being implemented in different studies.

The analysis of these articles tells that most work done connecting the use of blockchain in the healthcare supply chain is through Literature Review (70 studies). It is followed using Technology Model (16 studies) as BT model proposals or implementations. MCDM (13 studies) and empirical work (12 studies) are ranked after this. Very few amounts of work have been done in the form of Case Study (1 study), Hybrid approaches (3 studies) and the use of Mathematical based (2 studies).

V. DISCUSSION

As the prior conducted research falls into five clusters, a cluster wise discussion of the topics argued in the papers respective to these clusters has been presented –

Cluster 1 sheds light on healthcare supply chain issues that need to be sorted out. There are visibility issues that hamper proper tracking of medicines. Employee training and human resource practices deserve more attention [3]. Cold chain shipping, medicine counterfeiting, and supply chain visibility are additional challenges faced by pharmaceutical supply chains. The areas that require further research are waste management, risk management, and cold chain management. The cluster proposes that digitalizing healthcare supply chains and adopting proper technology can bring noteworthy improvements in the healthcare sector. It helps reduce paperwork, improve performance, improve diagnostic results, and enhance sustainability. Initial investments can be high, but they can prove beneficial in long-term investment. This group of studies also talks about the digital technologies' potential to fight against COVID -19 and the challenges it imposes. Problems such as fake information flow, funding distribution, and donation tracking, hampered food distribution and education, and uninterrupted supply of medicines and medical equipment, which are common in the COVID scenario, can be well tackled and managed with the help of technologies like blockchain [107].

Cluster 2 confirms a continuously rising trend in the publications on blockchain technology in recent years. The areas covered in the papers mainly include computer science, electronics, telecommunications, industrial engineering, and business fields. IEEE Access is the most productive journal and has the maximum number of publications. India has the most significant number of publications in its name, followed by the USA, England, and China. This group of studies also talks about integrating blockchain technology with IoT, artificial intelligence, machine learning, a cloud of things, etc. Blockchain features include decentralization, security, and trust, and its integration with the technologies mentioned above can help overcome the challenges faced by the technology like scalability and interoperability and improve the flexibility and performance of blockchain-based systems [112], [131], [133].

Cluster 3 shares that blockchain is evolving and has just entered the healthcare sector. Most of the proposals have been conceptual with significantly fewer practical implementations. Clinical trials, patient data management, medication traceability, data provenance and integrity, and main patient indices are among the healthcare-related concerns. Safety of data, timely accessibility, and cost savings are the demands of the healthcare sector that blockchain can justify. Decentralization, immutability, authentication, availability, security, and transparency are the motivations for the technology implementation in the healthcare sector. Blockchain helps better and secure medical information sharing, improves audit access, manages pharmaceutical supply chains, and stores both on-chain and off-chain data [108]. This cluster study identifies the contribution of distributed ledger technology to the healthcare sector with its applications such as electronic records management, health insurance, drug supply chain management, public health, education, and biomedical research. Most research has been done on electronic health records, data sharing, and access control. The emerging areas in this field include supply chain management, audit trail management, clinical trials, anti-counterfeiting of drugs, medical billing, biomedical research, and education [110].

The cluster discusses the barriers to technology adoption in the healthcare sector, including data accessibility, blockchain size issues, skill problems, scalability, interoperability, lack of experts, and infrastructural challenges. Post-implementation challenges include sustainability, security, confidentiality, 51% attack, and privacy issues [127]. Effective tackling of these challenges can boost the technology's widespread adoption. Different healthcare applications may require different blockchain types. This group suggests consortium blockchain as the best type for healthcare purposes as many studies support it. Both private and consortium are suitable with proper regulations and guidelines to improve interoperability without compromising security and privacy. OmniPHR, Gem Health Network, MedRec, MeDshare, etc., are blockchain solutions that help in patient-controlled data sharing. There is always a trade-off between blockchain usage's performance and cost. In blockchain-supported healthcare, Proof-of-Work and Practical Byzantine Fault Tolerance (PBFT) are the main consensus mechanisms. The two blockchain platforms most employed in the medical field are Ethereum and

TABLE 1. Article categorization.

S. No.	Methodology	Method	No. of Articles	References
1	Case Study		1	[69]
2	Literature Review	Review	24	[11], [12], [14], [17], [25], [31], [33], [36], [41], [63], [67], [73], [89], [93], [99], [105], [108], [112], [113], [119], [122], [137], [139], [148]
		SLR	35	[3], [4], [7], [10], [13], [18], [21], [22], [26], [28], [35], [37], [38], [39], [43], [44], [50], [53], [68], [72], [82], [84], [87], [92], [96], [97], [101], [102], [115], [121], [125], [128], [144], [151], [156]
		Conceptual Framework	4	[29], [59], [83], [141], [154]
		Discussions	7	[2], [5], [60], [80], [95], [104], [119]
		Bibliometric analysis	3	[46], [85], [94],
3	MCDM		13	[8], [16], [24], [45], [47], [52], [88], [90], [100], [116], [136], [140], [142], [155]
4	Empirical study	Statistical	11	[6], [19], [51], [78], [79], [98], [117], [118], [126], [130], [131]
		Survey, Focus Groups	1	[66]
5	Mathematical based		2	[61], [134]
6	Hybrid		3	[133], [138], [149]
7	Technology Model	Proposal	13	[1], [9], [23], [27], [54], [56], [57], [62], [64], [86], [91], [129], [145]
		Implementation	3	[42], [65], [85]

Hyperledger. The cluster also talks about the stakeholders' views about blockchain technology's adoption in healthcare. The stakeholders are still hesitant for hosting the technology. Physicians reluctantly clinch the technology, and healthcare service providers often trust healthcare data exchange as the current regulations don't support the same in an anonymized form. Blockchain adoption needs additional investments and resources like manpower training, human resource development, infrastructure, and ability to adapt to an existing group or a way of working. Due to an undefined framework and uncertain legal accountability over security issues, privacy, and medical errors, the stakeholders are not confident regarding the technology's use [124].

Applications of blockchain technology in the healthcare industry are shown in Cluster 4. Most of the published studies mainly concentrated on healthcare data management and medical records management. Many proposals have been given, like lightweight architectures, innovative contract-based systems, and health log data management systems to manage sensitive healthcare data. These applications help maintain patient-controlled, decentralized healthcare records that other users can access on the patient's agreement. Other proposals consider a blood cold chain management system to avoid delays in real-time access of blood to hospitals, vaccine supervision systems, and drug supply chain management systems for tracking drugs and reducing drug counterfeiting. The area-specific applications include sharing healthcare data in oncology and tele healthcare, and telemedicine. Other various technology applications in healthcare include COVID-based applications and uses in carbon trading.

The possibility of supply chain disruption due to blockchain technology is covered in Cluster 5. Supply networks are just now starting to apply blockchain technology. According to the studies in this cluster, supply chain problems including origin, authenticity, counterfeiting, tracking, and inefficiencies can be resolved by blockchain technology. Systematic data management, decentralization, immutability, traceability, and transparency offered by the technology help reduce costs and achieve other supply chain objectives like speed, sustainability, trustworthiness, flexibility, and risk management. The authors justify that using blockchain means incorporating more automation, involving fewer people, reducing interactions, and less paperwork to help achieve the objectives [106]. Transparency, traceability, automation, and trust are the major advantages of the technology. It helps improve customer-related and business-related relationships. The supply chain's stakeholders will feel more confident when technology is used since it can provide improved information sharing and supply chain quality control. It assists in keeping supply and demand from being out of balance. Blockchain contributes significantly to supply chain resilience and risk management, as well as enhancing supply

chain privacy and security. Supply networks can become more sustainable with the help of technology. Poor economic behavior and high sustainability costs act as barriers to sustainable development. The studies argue that the technology's coordination with modified business strategies helps attain sustainable development goals [71], [123].

This cluster also expresses that many organizations are still in doubt regarding the technology's adoption due to high implementation costs, scalability, interoperability, and lack of trust in technology. Other possible reasons include security, privacy, energy footprints, compatibility, and network complexity that deserve workable solutions. IT resources, financial backing, and government and top management support are needed to achieve this. Proper governance and standard regulations are desirable to make the blockchain systems interoperable. High investments are necessary to hire blockchain developers, and proper training needs to be imparted to the working staff regarding the technology's use. The studies stress a need to change business strategies to impact the technology after adoption better. The authors propose that blockchain is not the solution for every problem in supply chains and should be implemented only after analyzing its benefits and drawbacks [126].

VI. IMPLICATIONS, LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

This work offers relevant evidence to researchers, practitioners, policymakers, and managers regarding blockchain's use in the healthcare system. Theoretical contribution, managerial consequences, limitations, and future research objectives are explored in the sections that follow –

A. THEORETICAL CONTRIBUTION

This paper is a review study that makes significant theoretical contributions to the field of blockchain research. The purpose of this study is to present an overview of current healthcare research pertaining to blockchain technology. It offers the viewpoints of numerous researchers at the forefront of blockchain technology development, application, and conception. By including new, insightful research on blockchain's application in healthcare, this review added to the body of knowledge on the subject. Researchers and academicians can learn a lot from this study about the trends and dynamics in this field as well as the importance of blockchain technology in the Indian healthcare supply chains. The work identifies the relationships of different studies and their contribution to the respective topic through cluster formation. An overview of all these publications' work has been presented in this paper. This study tries to review the published work and propose cluster wise future research directions. Moreover, the study introduced a relevant framework for analyzing the five clusters of studies made in this SLR. Researchers can use this framework to analyze the current state of blockchain research in healthcare supply chains. It adds additional knowledge to the existing literature by presenting studies about past and present research in this domain and proposed future research directions. Most literature review studies have been done in this domain till now. There is more scope for empirical and mathematical-based work in this area to validate and generalize the findings in different contexts. Potential researchers in this field can benefit from the future research directions as proposed in the next section to conduct impactful research in this area. They can research the benefits and challenges of integrating the technology in the Indian healthcare sector with the help of the already-published literature. The findings will help academics identify the most suitable and practicable areas of the healthcare system to implement blockchain technology.

The transition to a blockchain-based healthcare system has already started, but there aren't many documented cases of cutting-edge healthcare organizations reaping the financial rewards of this novel technology. Because of the lack of reporting, there is insufficient data and, most notably, untested effects that are frequently anecdotal. The information that is currently known about the use of blockchain is purely theoretical. In the end, a lot more work needs to be done to fully realize the potential of these technologies. The absence of specific case studies and use cases may have to do with the intricacy and novelty of blockchain technology. In addition, the adoption of blockchain technologies must first overcome several obstacles. in the healthcare sector as discussed before.

B. MANAGERIAL IMPLICATIONS

This paper offers substantial guidance to the managers of the Indian healthcare industry. Healthcare supply chain managers need to take digitization initiatives for blockchain implementation in the healthcare sector. Hospital supply chain managers play an important role that is generally underappreciated, and senior management ought to give them more credit for their work and assist them in making investments. Consequently, the article provides supply chain managers with a fresh perspective on their responsibilities. The information from various studies discussed in this paper can be useful to successfully implement the alliance of blockchain technology with the Indian healthcare system. The benefits of blockchain technology like transparency, traceability, immutability, consensus, decentralized and distributed nature etc. can be effectively utilized by the healthcare managers. Managers can use blockchain to maintain accountability, track drugs and medical devices and reduce counterfeit products entering the healthcare supply chains. The distributed technology can be used to protect sensitive patient data and critical supply chain information and maintain its security and privacy. The real time visibility provided by the technology can help managers reduce stockouts or overstocking of drugs or medical devices and optimize healthcare products inventory levels. The technology can offer a shared and trusted platform to the different healthcare stakeholders like manufacturers, distributors, pharmaceuticals, regulators, healthcare providers etc. for better coordination and communication among them. To prevent any resistance to adoption, managers must make sure that

stakeholders are informed about the technology and how it is used. Managers can ensure safe and high-quality patient care by tracking and verifying medications and medical devices with blockchain technology. Managers need to utilize blockchain functions compatible with other technologies for better outcomes. When managers integrate blockchain technology with big data analytics or artificial intelligence to optimize the healthcare supply chain, they can make better data-driven decisions.

Blockchain technology is a newcomer to the healthcare industry, and to integrate the enhanced procedures into the current systems, senior management support is needed. It becomes necessary to promote a positive attitude about blockchain among workers and medical staff by the top management. The management of the healthcare organization thinking about switching to blockchain technology may incorporate the recommended framework into their strategic planning agenda and create detailed strategies to achieve the goals. Blockchain technology enhances the healthcare ecosystem's capacity to satisfy societal and customer demands. The top management shall understand the potential and suitability of blockchain's applications in the Indian healthcare sector to manage associated healthcare issues. Governmental organizations and policymakers can build legal frameworks, laws, and standardized protocols for interoperable healthcare blockchain networks accepted globally. It is recommended that small businesses obtain BT services from reliable companies, and that strict regulations be implemented by the government to prevent security breaches. Practitioners can use the literature provided in this manuscript to better understand the use of blockchain and make improved decisions for managing Indian healthcare supply chains. This work can help managers better analyze blockchain technology and improve their decision-making regarding its adoption in healthcare organizations. Many challenges come in the way of blockchain adoption like privacy, security, cost, government policies, regulations etc. It requires exploring the challenges to blockchain's adoption in the Indian healthcare sector by research scholars. Following this, managers can make a roadmap first and suggest strategies for tackling these adoption-related challenges and take advantage of the technology. There is a need for healthcare organizations to adopt suitable business policies before implementing the technology to get desired benefits. Additionally, the blockchain platform can link consumers who are open to having their health data used in studies in a health data marketplace with research organizations. The blockchain technology would allow researchers to connect with patients across the world. This will raise the possible sample size for study and raise the accuracy of the findings.

Early blockchain implementations in the healthcare sector have demonstrated that, for adoption to be effective, relationships between healthcare professionals, patients, and the pharmaceutical industry must be redefined. Prior to reimagining the healthcare system using blockchain technology, it is necessary to address legal and regulatory difficulties as well as blockchain-related issues. Even though blockchain technology in the healthcare industry is still in its infancy, there are many exciting applications. Even if the healthcare sector hasn't yet adopted the technology extensively, its uses will only grow in the next years. There aren't many studies on the topic, thus further research with real-world applications will be helpful in the future. The need to promote blockchain adoption is becoming more pressing among academics for additional theoretical research as well as in the business sector for practical implementations, given its potential for efficiency and dependability. Healthcare supply chains must be dedicated to having the same goals and principles and must be in alignment with this shared innovation because they are interdependent webs of diverse stakeholders' interests and behaviors. Managers need to make sure that their interests and objectives remain aligned together. To promote and expand its implementation, managers need to keep the stakeholders engaged together.

C. STUDY LIMITATIONS

Conducting a systematic review depends on the quality of the papers referred to in the study. This review was limited to journal articles indexed in Scopus, ScienceDirect, Web of Science, IEEE Explore, EBSCO, Taylor and Francis and Springer. The search information was restricted to keyword use and other articles were not considered. In addition, articles with blockchain's use in healthcare supply chains were mostly preferred. The primary constraint of this study is that its findings were pertaining to the phrase ''blockchain in healthcare,'' rather than technologies associated with the healthcare sector**.** Only English language papers were considered for this study; therefore, cross-cultural differences were not accounted. This study is a conceptual work with no statistical significance. The research structure is conceptual; to provide a more thorough analysis, subsequent studies should test the stated premises empirically. The systematic reviews lack statistical significance and exhibit some limitations, which are crucial for any quantitative research.

D. FUTURE RESEARCH DIRECTIONS

As the researchers' interest in this topic has been rising with time, it becomes relevant to report the current state of literature and propose future research directions to avoid repetitive work in this area. Several research gaps have been identified after the review of existing studies. Following are the cluster wise future research directions –

Cluster 1 aims to study human resource practices that should be considered in the future, waste management, cold chain management, medication visibility and tracking, and staff training. The studies focus on waste management and pollution prevention in reverse logistics and quality management areas and indicate them as future research work. Blockchain can help with management of returned goods, keeping track of whether they are properly disposed or recycled. It can help track the distribution and production of goods, maintaining the quality of products that reach

consumers. Researchers suggest product recall management, sustainable performance measurement and setting of new benchmarks, designing new regulation systems, and the effect of incentives on sustainable activities deserve exploration. The capabilities of blockchain including transparency, security, accountability, and traceability can play a pivotal role in improving these areas. Finding organizations' characteristics that can help improve digitalization implementation beyond the scope of top management through a global comparative study with health networks of those digitally matured studies is also suggested. This cluster also proposes comparing Hyperledger and Ethereum-based blockchain systems for future work as both have different advantages and suitability.

Cluster 2 stresses investigating blockchain's integration with IoT, data science, artificial intelligence, etc., and crowdsourcing applications. The integration of these technologies with blockchain can enhance their capabilities, applications and use cases. At the same time, new challenges like interoperability, security, privacy concerns can arise which can become a topic of future research. Some studies have also proposed integrating blockchain technology and collaborative business management. Future research might examine the potential effects of blockchain technology on business models in the domains of supply chain management, project management, asset management, and contract management. Research on security and critical management focuses on replacing lost or compromised keys and deserves attention. A thorough investigation is needed to find out how digitalization can be linked to cost. Another recommendation from authors in this cluster is investigation of how digital transformation in healthcare can affect intellectual asset management.

Cluster 3 recommends addressing topics such as prescription management, public health, health insurance, pharmaceutical supply chains, and so on. Blockchain technology has great promise for revolutionizing healthcare supply systems. Blockchain can be used to handle patient data and track medications through supply chains, among other issues facing the healthcare sector. Studies suggest looking into digital health standards and researching the numerous types of blockchains—public, private, consortium, and hybrid—that are utilized for different healthcare applications. Each type of blockchain has pros and cons of its own. Monitoring the progress of healthcare applications and smart contracts for healthcare improvement needs attention which is an ongoing and complex process. Blockchain can aid in making the whole process transparent, secure, and effective. Integration of blockchain technology with business processes that can improve healthcare processes functionality and examine the consequences of blockchain use in healthcare supply chains is also proposed as a future research direction. The technology can help in improved supply chain management, streamlined data sharing, enhanced traceability and accountability and improved payment processing while issues like regulatory compliance and data privacy and security also need to be taken care of with its implementation. Blockchain-based research for patient movement tracking, donation, and outbreak tracking useful in COVID scenarios is also suggested by the cluster. Investigation of patient acceptance of blockchain, assessment of users' expectations, and factors determining their satisfaction is also suggested as a future research direction. Both qualitative and quantitative studies can be done in future to assess users' expectations and experiences with the technology. Better assessment with real-world healthcare data and exploration of collaboration between researchers and healthcare organizations is advised as future work. Monitoring and tracking of supply chain within hospitals needs future investigations and remote patient monitoring for vulnerable patients.

Cluster 4 proposes exploring healthcare big data management and off-chain security of blockchain. Management of big data health records by health log data management techniques needs to be carried out as discussed by cluster studies. Health log data management techniques help collect and analyze health data from different sources. Furthermore, it is thought that the blockchain may be successfully integrated with big data analytics, namely regarding data administration and analysis. Blockchain technology can be used by data management to store information decentralized and safely. The data's legitimacy can also be confirmed by the blockchain defence component. Medical documents kept on shared devices, for instance, would be hard to misplace and wouldn't be subject to theft without the owner's consent. Patients and medical experts can assess this blockchain-stored data. Technology has allowed patients to have more control over their data and allows healthcare practitioners to securely access it. Investigation of health data cross-border sharing, and related standards and regulations are suggested. Different countries use different regulatory frameworks, diverse standards for sharing healthcare data. This issue requires careful investigation of factors like security, privacy, regulatory frameworks and how blockchain can solve these problems. Analysis of blockchain-based applications for fair and transparent clinical trials and verification of drugs. Blockchain's features like transparency and traceability can revolutionize these areas and future work can include assessing its impact. Improvement of blockchain-based systems in managing large healthcare datasets at a low latency level is advised by studies for future work as blockchain too has a limit to store. Blockchain-controlled healthcare scalability deserves attention as healthcare is a vast industry, and the number of patients keeps increasing every day. Blockchain technology is not yet mature enough to be decentralized. Its widespread adoption in various public and private healthcare organizations needs attention in future. Future work can include blockchain adoption impact on different healthcare stakeholders and their perspectives regarding the technology. Patient's acceptance of blockchain and studying the factors regarding their expectations and satisfaction deserve attention. Future studies will investigate how blockchain technology might be used to make smart, dynamic contracts that manage cross-domain diversities.

Surveying other medical specialists may also be a part of future research to precisely assess the platform's efficacy, accuracy, and usability. to completely comprehend the advantages and possible disadvantages of technology adoption in the healthcare industry. Future studies will also include focus groups with patients, physicians, and developers to learn more about how blockchain impacts organizational processes in healthcare facilities.

Cluster 5 proposes the addressal of technical issues like interoperability, scalability, throughput etc., that hamper supply chain performance. Blockchain adoption for a specific industry or specific supply chain objectives can be used for future research work. Healthcare or manufacturing sector can be chosen and blockchain's effect on supply chain objectives like cost, quality, responsiveness, flexibility etc. can be taken up for research. Researchers have proposed the need to redesign supply chains with more resilient strategies to reduce disruptions due to COVID. Blockchain's features like transparency, traceability and decentralization can be of help in mitigating supply chain risks. The studies in this cluster further suggest the performance evaluation of blockchain-based systems in supply chains, which can be in terms of cost, speed, scalability, and security. In general, identification of joint standards across blockchain platforms like Ethereum and Hyperledger for their better integration and working at a comprehensive level can be a topic of interest for researchers. Joint standards can be used in smart contracts use, consensus mechanisms, interoperability, data structures etc. which can make easier the adoption of blockchain based systems in business or healthcare. The studies in this cluster have also proposed investigating blockchain's role in sourcing, partnerships, and coordination in international trade in supply chains. Blockchain based systems can enhance coordination, transparency and traceability which can help better manage complex international trade operations. Other analyses recommend more research on confidentiality and privacy aspects in supply chains as shared data becomes visible to all network members. Exploration of blockchain-enabled demand-supply management, digital trust, and inter-organizational business process through smart contracts is further suggested by few studies.

VII. CONCLUSION

An efficient healthcare system is essential to the development of a country's economy. In the present healthcare landscape, more and more advanced technologies are required. The patient-centric approach, which emphasizes prompt access to healthcare resources and services, is becoming more and more prevalent in the healthcare industry. Blockchain technology can offer society high-quality services and sufficient care. Because there haven't been many noteworthy studies in this sector, the number of articles has increased, but it's still unclear what has already been researched and what must be investigated further. The literature on the possible applications of blockchain technology in the Indian healthcare sector has been thoroughly examined in this study. The purpose of this work is to identify the research gaps pertaining to the healthcare industry and to propose future routes for blockchain research in this field. The study that was presented made it easier to analyze the state of blockchain research in the medical field. The results of the published articles are synthesized, and cluster-wise future research agendas are proposed. The study presented what problems the Indian healthcare sector or healthcare supply chains have been facing and how blockchain technology applications can contribute to managing the healthcare issues of drug counterfeiting, fragmented patient records, medical data security, privacy, medical insurance fraud, etc.

Blockchain is at a nascent stage and has just entered the healthcare sector. The publications in this area have been rising steadily in recent years. IEEE Access is the most productive journal and India is the most productive country in terms of publications. Most work done in this domain is conceptual or theoretical, mostly literature review studies, with few empirical analysis and practical implementations. The published work mainly focused on medical data management, data sharing and access control. These studies also proposed the technology's potential to bring improvement in areas like drug supply chain, biomedical research, remote patient monitoring, medical insurance, education etc. Blockchain technology's healthcare applications include EHR management, drug supply chain management, telehealth care applications, vaccine supervision, blood cold chain management, COVID-based applications, etc. The Indian healthcare sector requirements are a subset of blockchain technology applications. Digitizing healthcare supply chains and adopting suitable technology like blockchain can bring significant developments in the Indian healthcare sector. Blockchain can help solve healthcare supply chain issues like counterfeiting, provenance, tracking, authenticity etc. The technology's use will help build healthcare supply chain stakeholders' confidence and trust. This work contributes to the existing body of knowledge in this domain, providing insights to policymakers and practitioners. The provided framework presents the current state of work in this area. In the future, BT's adoption in the Indian healthcare sector will not be easy as some challenges will be associated with it. Many healthcare organizations doubt the technology's adoption due to challenges like security, privacy issues, high implementation costs, scalability, interoperability, lack of trust, complexity etc. Identifying these adoption barriers and their appropriate solutions is essential for convincing the stakeholders regarding the technology's adoption in the Indian healthcare organizations.

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